ENGINEERING

An Illustrated Weekly Journal

35 & 36 BEDFORD STREET, STRAND, LONDON, W.C.2 - - TELEPHONE: TEMPLE BAR 3663

Vol. 180 No. 4682 — LONDON, FRIDAY, OCTOBER 21, 1955 — PRICE 2s.

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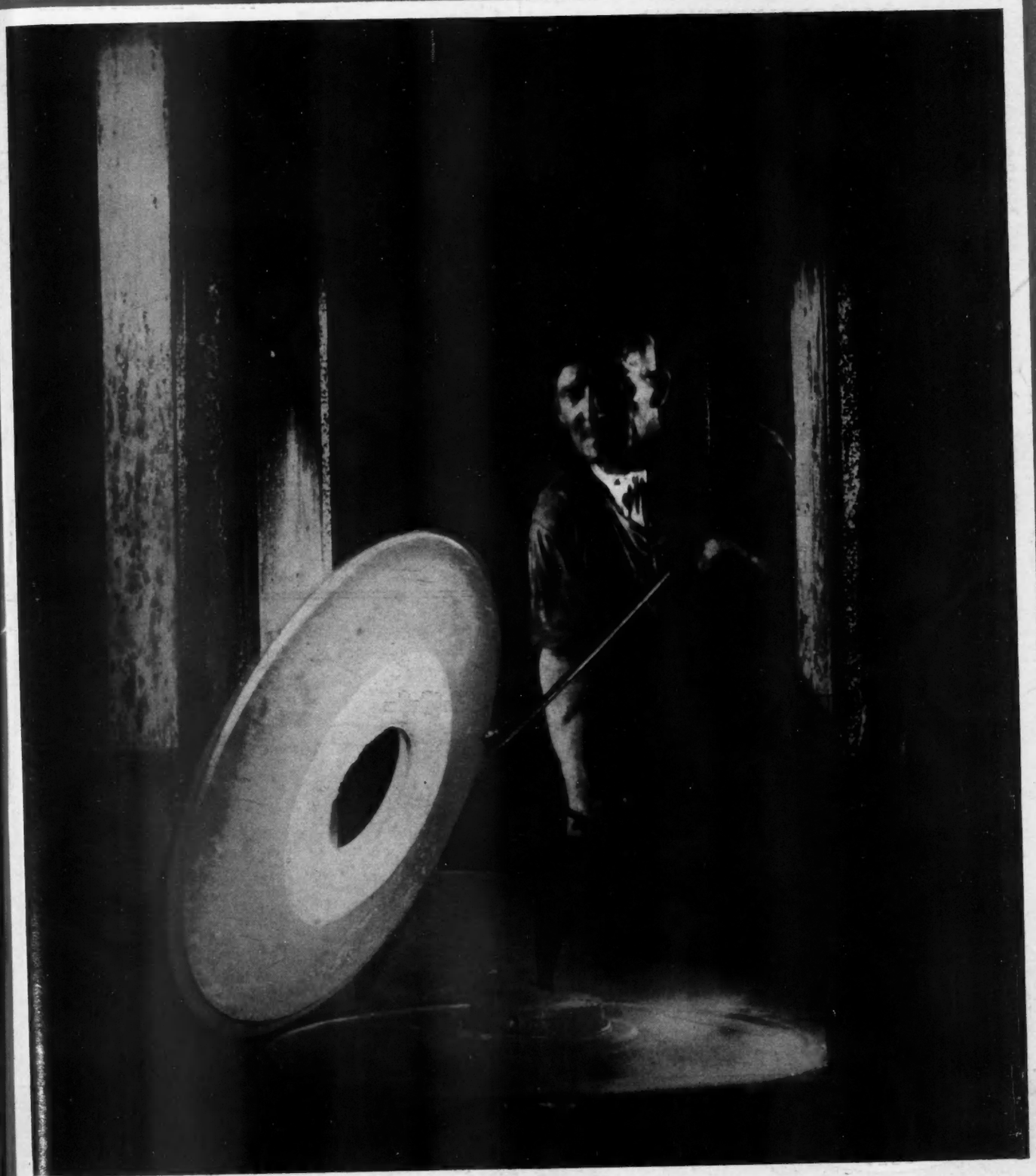

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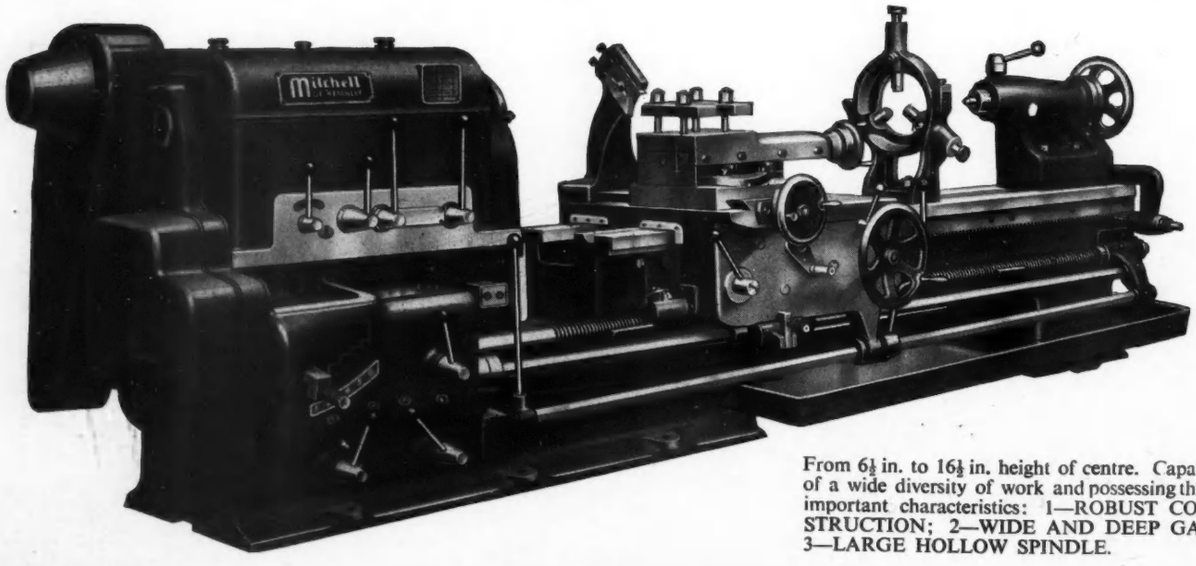

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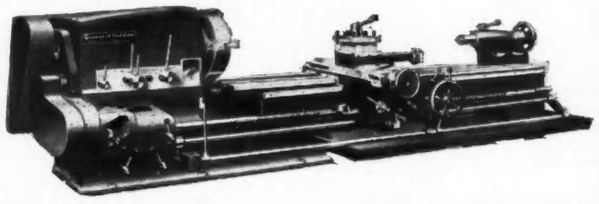

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Published every Friday by Engineering Limited
35 & 36 Bedford Street, Strand, London, W.C.2
TELEGRAPHIC ADDRESS *Engineering, Lesquare, London* TELEPHONE *Temple Bar* 3663

Subscription Rates for 12 months, Inland and Abroad £5 10s., Canada £5 5s. Subscriptions for periods of less than 12 months are based on the price of a single copy including postage [2s. 3d.]

THE MOTOR SHOW

THIS year's London Motor Show finds the industry on the defensive. Resolute foreign competition, particularly from Western Germany, has recently made serious inroads into the export markets in Europe and the United States. With the praiseworthy flexibility which has characterised their overseas operations, British car manufacturers built up the Australian and New Zealand markets until they were the two most important outlets, only to have them severely curtailed by import restrictions. The effects of these restrictions may be offset to some extent by the growth of overseas assembly plants, particularly in Australia, New Zealand and South Africa, and increasing attention is being given to India and South America, but the trend of affairs has lent support to critics who allege that our salesmanship is poor, that our designs are old fashioned, and our cars inferior in quality. One answer from the industry is that Germany had so much leeway to make good that her progress was bound to appear spectacular, and that both countries are exporting about 45 per cent. of their output. And Britain is still the world's largest exporter of motor vehicles. There are signs, too, that the German industry may soon have to face the rises in labour and material costs which have made nonsense of so much cost planning in the British industry in recent years.

The motor industry is a very large purchaser of goods and services from outside (as we showed in the first of two articles published in last week's issue), and its costs are heavily inflated by the slowness of the country's transport system. It is in a peculiarly frustrating position; building the vehicles which could speed communications, but denied the roads on which they could be profitably employed. Many elements of its production costs are thus beyond its control. One of the directors of the Standard Motor Company complained the other day that there is still too much steel being imported at an extra cost of £20 per ton, and there is still a shortage of steel forgings and stampings.

The industry is now heavily committed to a large expansion programme which should make an important contribution to the problem of reducing the cost per unit, but it faces still stronger competition from the industries of the United States, Germany, France and Italy, which are also expanding rapidly and must find outlets for ever increasing numbers of vehicles. There is also a growing tendency for other countries to establish their own car industries. Sweden, Spain, the Argentine, Australia, all have cars of their own completely built within their borders. The Japanese industry has become an exporter again and Canada, thanks to the output of her American-controlled assembly factories, has become one of the world's largest car producers.

At home, the industry has to solve the problems of preserving enterprise and flexibility in an economy already heavily extended. Full employment brings immobility of labour and strikes against "redundancy." Full order books induce indifference or even active resistance on the part of suppliers when designers require new parts which differ from the standard lines. There are signs that in items like electrical equipment and body hardware, standardisation has been carried to a point where progress is being retarded and designers find it difficult to give their products the necessary individuality. There has, in fact, been remarkably little pioneer work by the British industry since the war. Often their caution can be justified in the light of subsequent results. The much admired light-alloy Dyna Panhard recently acquired a steel body shell, partly to bring the price down but also, it is understood, because of the difficulty of ensuring consistent quality in the welded light-alloy sheet structure. Some expensive development work has also been done overseas on independent rear suspensions which have often shown serious defects.

A certain caution is therefore reasonable in the interests of the industry and its customers, but it has been carried to considerable lengths. Even if independent rear suspension is not adopted, the use of a rigid axle located by nothing other than a pair of half-elliptic springs is no longer really adequate for cars with a 100 m.p.h. performance. We had hydraulic-pneumatic suspension systems on the road ten years ago, but none has yet reached production, and although British production brakes are of excellent quality, the disc brake pioneered in this country, has first gone into production on a foreign car.

It was natural that the American industry with its vast home market should be the best equipped to solve the costly development and production problems of the fully automatic transmission, but it was a pity to let France win a clear lead in the move to easier driving on small cars with the all-synchromesh gearbox and centrifugal clutch on the 2CV Citroen, and the electromagnetic Ferlec clutch on the 4CV Renault. There are also many foreign critics of the appearance of our family cars, which they find ungainly and old fashioned, in contrast to our sports models which meet with universal admiration. There is therefore much food for thought in the international display at Earl's Court.

Weekly Survey

Cover Picture: *As a method of manipulating metal, drop forging has the advantage that, with a good design, the fibrous structure of the original billet is retained and moulded to the form of the finished component, so developing a condition contributing towards high strength. This week's picture shows the completion of the forging of an air-compressor disc for a gas turbine.*

* * *

Impact of Commercial Television

The arrival of commercial television under the control of the Independent Television Authority creates a new factor in British industry. Its impact on the engineering industry is likely to be both direct and indirect. It is much too early to say how powerful an influence commercial television is going to have on engineering but it is as well to take account of the nature of its influence from the beginning.

Sir Robert Fraser, Director General of I.T.A., told the Incorporated Society of British Advertisers at Hastings recently that within twelve months 30 million people, or 60 per cent. of the population, would be covered by commercial television transmissions. By September, 1957, the north-east coast, Wales, Scotland and south-west England would be covered as well. Thus within two years I.T.A. will be operating as complete a coverage as the B.B.C. and there will be added, in consequence, an additional powerful influence on three matters which are significant to the engineering industry. These are the demand for new and replacement equipment in the radio communications industry, the rate of change towards higher definition and colour television, and the spending of advertising revenue.

I.T.A. begins alongside the B.B.C. committed to 405-line definition in monochrome and it will be a major issue for both organisations as to whether a colour system is to be introduced on 405-line definition or at a considerably higher line definition—alternatives which have already produced two powerful and as yet unreconciled schools of thought. It is interesting in this connection that Mr. C. O. Stanley, chairman and managing director of Pye Limited, said last week that he would prefer the adoption of 625-line definition but he was against spending large quantities of public money on developing colour television in this country until further progress had been made with it in the United States, and we could learn from the expensive failures which had been experienced in that country.

Important as are these technical issues for the radio industry, the indirect impact of television on commercial advertising and the demand for consumer goods may be even more serious for the engineering industry in the long run. Less than 4 per cent. of adults in the I.T.A. area so far have been found to have watched commercial television in the average evening. It is much too early to say what will happen when I.T.A.'s coverage is wider, when the commercial advertising experts have improved their techniques and the public have adjusted themselves to watching advertisements on the screens once the novelty has worn off. It will be surprising, however, if in the long run there is not formidable pressure to switch from capital goods to consumer goods industries.

* * *

Campbell's Bluebird

Full technical information on the design of the Bluebird III, which set up a water speed record of 202·32 m.p.h. last July, is not likely to be released until Mr. Donald Campbell returns from the United States. A paper to the Institution of Naval Architects will probably be the medium of release. The crucial configuration of the Bluebird was the work of the two brothers Norris, young consulting engineers who spent long hours carrying out wind-tunnel tests at the City and Guilds College.

The value of wind-tunnel tests in developing the form of Bluebird III was described by Mr. P. T. Fink, a lecturer at the City and Guilds, in a talk to the Old Centralians last week. There are two components of force acting on the hydroplane craft when it is "planing" across the water at speed—drag and lift. It is the air lift component, potentially dangerous, which was mastered in the wind tunnel; it could not be calculated solely by theoretical means. About 25 different model configurations were tried out. The lift was less than the weight but it always acted forward of the centre of gravity. Films of John Cobb's disastrous run revealed that his boat pitched badly at about 200 m.p.h.; it oscillated as much as 6 cycles a second and the resultant accelerations were clearly severe. Model tests showed that the Bluebird would be similarly affected if run at high speed on disturbed water having a wavelength of 50 ft.

Full-scale trials started on Ullswater last February. Ironically, trouble was experienced at low speeds (5 to 10 m.p.h.) before the craft was planing. Water spray got into the Metropolitan-Vickers jet engine and extinguished combustion. Sheet metal between the sponsons and the hull cured the trouble but necessitated further model tests to ascertain the effect on air lift. Some model tests were also conducted on a pond at Mr. Campbell's home; then the third and last series in the wind tunnel and early in July Bluebird III returned to Ullswater in its record-breaking form.

* * *

Wanted: Funds for Transport

A most detailed statistical analysis of the capital structure, employment, operating costs and revenue of Britain's transport industries was presented to the Institute of Transport by Mr. Peter Masefield in his presidential address last week. One of his conclusions is that transport in Britain is a highly profitable business and that it could be more so were it allowed to spend more freely on modern plant and equipment. In Mr. Masefield's view, operating costs, and hence fares and tariffs, are higher than they would be if transport had not been "starved of investment since the war."

The railways in particular are suffering from very high interest charges on "a back-breaking capital of £1,500 million" much of which represents obsolete assets. This turned an operating surplus of £20 million into a net loss of £22 million in 1954, and if it could be alleviated by Government action the railways could take on a new lease of economic life. The break-even load factor for operating costs, at 36 per cent., is the lowest of any form of transport. In the field of air transport, Mr. Masefield postulates that the present 5 per cent. surplus on operating costs is far too low to allow for flexibility in investment plans, and he would like to see a margin of not less than 15 per cent. This, he says, is essential if interest is to be paid on capital and operators are "to feel safe against the vagaries of market and supply conditions." If this margin were to be extended to all forms of transport, it would represent a return of about 7 per cent. on total capital investment—almost double the present rate—which would be invaluable for capital expansion. The practice of running a transport system on inadequate and obsolete equipment, as has been done in this country for years, is incompatible with successful expansion.

* * *

Monorail to the Airport

Dealing with "forward possibilities," Mr. Masefield concludes that railway trains running on tracks as we know them to-day are "not likely to be capable for normal working speeds" of much more than 100 m.p.h., and he revives the old idea of "monorail" suspended railways. A particular application discussed at length is for passenger-carrying between airports and city centres. He lists five major requirements to enable the monorail to "knock out the helicopter and the bus": the operating cost, including interest on capital and depreciation of equipment, should not exceed 4*d.* per passenger-mile; seating capacity for 150 passengers; normal operating speeds upwards of 150 m.p.h.; a low noise level—using pneumatic tyres—and the ability to operate to a high frequency in safety.

Mr. Masefield then proceeds to build up an estimate of the capital expenditure needed to provide a service from London Airport to the Cromwell Curve Air Terminal site, a distance of 10¼ miles. Seven units would be needed to provide for a peak service of six return trips an hour, each round trip taking 1 hour 10 minutes incluing one hour for loading and unloading passengers and baggage. The total capital requirement is put at about £12 million, including £9½ million for track, terminals and stations. The annual capital cost, including interest, is £882,000, assuming the cars are written off in ten years and the track, signalling equipment and land purchases over 50 years. Adding to this the running and maintenance costs, the total annual costs would be around £1·22 million, equivalent to 2·7*d.* a seat-mile.

Mr. Masefield concludes that "the monorail thus appears to have serious possibilities—combining high speeds with reasonable costs—for certain limited purposes over high-density short routes," but that "its novelty is an impediment to its exploitation."

In the United States the search for lower rail transport costs has resulted in a proposal for remote-controlled driverless trains travelling at 86 m.p.h. "that would make the 230-mile trip from New York to Boston in two and a half hours, with all curves taken at full speed." The saving in time—some two hours—may indeed make this development pay, but one feels that Mr. Masfield's monorail may appeal rather more to the average passenger's self-preservation instinct.

* * *

Half the Year's Trading

In the first half of this year the United Kingdom had an overall surplus on its current account with the rest of the world of £17 million. This works out at £148 million less than in the same period of 1954. Three points are of particular interest in these figures. First, the deterioration in the position since the first half of 1954 has been due, to the extent of about £100 million, to an increase in the visible trade deficit with non-sterling countries, which means in effect that the rest of the sterling area has been running its imports at a much higher level compared with exports over the 6 months' period. This is another side to the recent balance of payments difficulties which have been encountered in Australia and New Zealand. Secondly, invisible earnings—especially those from oil—have been disappointing. A big rise in the expenditure of oil companies which has more than offset the increase in their earnings has occurred owing to the resumption of refining and shipment operations in Iran. Thirdly, the performance of the United Kingdom trading account has been fairly satisfactory and there is every indication that the export drive, in which the engineering industry plays such a crucial part, has gone well. It is very apparent, however, that any sudden slide in the economic fortunes of one or more of the Dominions or of those colonial territories which have a big dollar-earning potential cannot possibly be held by a short-term special effort by British industry in the export markets.

The first half of the year is usually favourable for the U.K. balance of payments because the heavy import bills for foodstuffs have not to be met until the late summer. A surplus of £17 million, even if it is found in due course that the statisticians have erred on the pessimistic side, is quite inadequate as a reserve against the seasonally less favourable conditions in the second half of the year. Even if the seasonal swing

against the sterling area is a mild one this year, the position will probably have been reached where the United Kingdom is running a small surplus which is quite swamped by a substantial deficit from the other members of the sterling area. This will be a dangerous situation if it continues for it will require patient and tactful pressure on the rest of the sterling area to persuade them to balance their international account in order to put the trouble right. This is a procedure which may take time. Neither the pound nor British industry can carry for long a chronic deficit from the overseas members of the sterling area.

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The Importance of Farmers

Any doubts there may have been about the political importance of the farming community should be removed by the insistence of the Ministry of Agriculture, Fisheries and Food that the Government has never intended that they should go short of capital. Whoever may get hurt in the credit squeeze it will not be the farmers. The Government's wish is that farmers should not go short of working capital or be restrained from carrying out short-term improvements. Reductions of credit are to take the form of deferment of long-term plans. He would be a bold civil servant, however, who would draft a declaration of the Government's intent which would make it quite clear to a bank manager how he was to differentiate in many cases between a short-term and a long-term development in farming. There are all sorts of arguments which can be produced in the farmer's favour but the upshot of them will be that there is to be a special and favourable dispensation for the farming community.

That this should be so is by no means against the interests of the engineering industry. The farmer is to-day among its best customers. An assorted selection of methods of payment which cover hire purchase, deferred payment, joint ownership and ordinary hire, place at the disposal of the farmer a substantial quantity of plant and machinery each year. In 1954, out of a gross capital formation by British industry of £2,452 million, agriculture accounted for £84 million, that is for almost 3½ per cent. Taking plant and machinery alone, agriculture accounted for £56 million out of £853 million, or over 6½ per cent. While it does not rank with the public utilities as a source of business for the engineering industry it is worth recording that in 1953 (the latest date for which complete data are available) agriculture made a larger financial provision for buying new plant and equipment than any single manufacturing industry, except chemicals and oil refining which together accounted for £79 million, although by taking vehicles and engineering together it is possible to make these total £73 million. Apart from these groups, agriculture was well ahead of coal mining at £35 million, iron and steel at £44 million, precision instruments, etc., at £32 million and the food and drink industries at £42 million. The mechanisation of agriculture has in fact given the engineering industry a vital interest in the prosperity of the farmer.

★ ★ ★

Steel Brake on Expansion

The figures released by the Iron and Steel Board last week only partly reflect the mounting uneasiness about iron and steel supplies. There has been since the holidays a marked accentuation of shortages, particularly of alloy steels, drawn and rolled products, and a most unwelcome return to the "psychology of shortages" so universal in the 1940's. To put it bluntly, those companies who have the necessary bargaining power are building up their stocks, to ensure against delivery delays and losses of production, and thus making the supply position worse for the rest of the industry.

The root of the troubles lies in the divergence of opinion, based on estimates of future demand, between the iron and steel industry and some of its customers concerning the rate of increase in the latter's output. Taking what they call a long-term view, the steel manufacturers have assumed an overall rate of 5 per cent. per annum in capital investment until 1960. Apart from the fact that this is being exceeded by most steel-using industries, increasingly there are signs that the production per unit of capital investment in steel-using manufacturing industries is rising and could rise much more if certain labour problems relating to shift work were solved.

It may be, of course, that the Chancellor will, through Bank Rate and credit controls, effectively reduce home demand and thus falsify these industries' estimates. Yet if this happens it will be, at least in part, due to the drain on our dollar resources of steel imports. The danger of tinkering in such a hit-and-miss manner with natural industrial growth—a growth that has in fact been the basis of expansion of the national incomes of the United States and Germany in the past decade—is obvious enough. To consume more and so raise the scale of output and reduce manufacturing costs may well be the only way left open to us to increase exports in relation to imports. The iron and steel industry could be proved right by events, but would in this have been greatly assisted by its own inability to sustain a steeply rising output. If the shortage of certain types of steel becomes more acute the cost to industry—of production hold-ups, underemployment, broken delivery promises, etc.—is likely to be higher than it can afford in order to keep up its exports.

★ ★ ★

Weak Road Signs

The new regulations for road traffic signs (published recently by H.M. Stationery Office but yet to be approved by Parliament) contain welcome improvements but do not go nearly far enough. The main fault lies in the apparent assumption that a driver's reaction to signals is a matter for quiet despair or individual guesswork, rather than a subject for experiments on an adequate scale. Little use is made of the reliable data on vision, or of the large functional differences which have been shown between different forms, proportions, colour contrast, etc., of letters and numerals. Those chosen, while aesthetically pleasing, are inferior in legibility to some alternative designs. Some of the other regulations are at best matter for dispute; e.g., there is no evidence to show that flashing lights are better than steady lights on safety beacons. A signal should command attention quickly, but not make recurrent cyclic demands to the possible detriment of observation elsewhere. The distinct possibility that flashes have this effect needs more rigorous investigation.

Some new signs are a definite improvement on older types. A picture of running children gives a more meaningful signal of the approach to a school than the previous symbol of a torch. The basic idea of direct pictorial signs should be carried much further, to encode the many signs bearing more or less lengthy legends, which all reduce to the simple primary message of "take extra care" or "slow down." Another large class of signs prohibit or else demand a particular action and these have legal force. The present attempt at pictorial coding is to surmount the various classes of signs by triangles, circles or rings. The need for experiments, rather than naïve assumptions, to test their effect was brought out in questioning ten experienced road users, none of whom could state the precise meaning of the current symbols.

The Ministry regulations generally reflect much experience and scientific tests of the physical factors which affect road safety—road surfaces, brakes, steering gear, etc. But comparatively little effort is made to obtain information on how road users respond to signalled information. Yet relatively few accidents occur because of physical failures, such as the car failing to go in the direction in which it is pointed. Most occur because someone decides to point it in the wrong direction. This is surely the area which demands most attention, although it is currently receiving the least.

★ ★ ★

A College Comes to the Works

The importance, for engineers working in advanced technological fields, of increasing the depth and breadth of their knowledge of the basic sciences is usually well appreciated by their employers. In the United Kingdom, for instance, promising young engineers in the aircraft industry may be given the opportunity for post-graduate studies at the College of Aeronautics, Cranfield, or at one of the universities. In so doing, the firms lose their services temporarily, but the subsequent gain outbalances the temporary loss.

An interesting alternative approach to this problem—possible only in a large organisation which counts its qualified engineering staff in thousands—has recently been introduced in the United States by the United Aircraft Corporation, East Hartford, Connecticut. Instead of sending their engineers to college, they have brought the college, in conjunction with the Rensselaer Polytechnic Institute, to the Pratt and Whitney division. The Hartford Graduate Center of the Rensselaer Polytechnic has been opened, and about 215 students—all full-time engineers and scientists in the service of the United Aircraft Corporation—enrolled for courses in aeronautical engineering, mathematics, mechanical engineering, mechanics, nuclear technology, physics, or management engineering. The courses will extend from 2 to 2½ years. Those enrolled will spend most of the day in their jobs and the balance of the day and evening attending classes.

★ ★ ★

New Fleet for B.E.A.

The recent announcement by Mr. Peter Masefield that British European Airways is to have a fleet of propeller-turbine 93-passenger Vanguards confirms that the policy of reducing flying costs is to continue, and a number of features of the new aircraft are likely to contribute towards this end. The Vanguard, or Vickers V900, is designed to fulfil B.E.A. requirements for an airliner that "will set a new world standard in its class, and will be ahead of all known competition in reliability, speed, economy, comfort, pilot handling, maintenance characteristics, ability to make quick turnrounds and in general passenger appeal." An important feature intended to increase the economy of operation is the "double-bubble" construction and the provision of a large lower freight space, so that in off-passenger-peak periods, with only 30 per cent. of its seats filled, the aircraft will be able to run at a profit.

The Vanguard, which should be ready for delivery by 1959–1960, will be powered by the Rolls-Royce RB109, the Tyne, and will be approximately 118 ft. in span and length with an all-up weight slightly in excess of 100,000 lb. The design cruising speed is 425 m.p.h. when the engines are delivering full power, but initially power output will be limited to 4,000 h.p. It will be capable of operating on all major routes above 200 miles, but thicker concrete might be required for certain runways, as for example at Jersey airport. Sir George Edwards, managing director of Vickers-Armstrongs aircraft organisation, said on the occasion of the announcement that to hasten delivery, production jigs would be made straight from the drawings.

Mr. Masefield also reported that B.E.A. had already ordered 22 Vickers Viscount-Major (V 802) airliners, deliveries of which would begin next year, and were placing further orders for Viscount-Major (V 806) aircraft powered by Rolls-Royce Dart R.Da.7 engines giving a cruising speed of 360 m.p.h. There would be no more piston engines in B.E.A., he said, and the new turbo-propeller aircraft would help to keep B.E.A. in "a permanently profitable position."

"MOST PROGRESSIVE LOCOMOTIVE ENGINEER OF HIS TIME"

SIR W. STANIER'S RECOLLECTIONS OF CHURCHWARD

Sir William Stanier, F.R.S., who served on the Great Western Railway under Churchward and was subsequently Chief Mechanical Engineer of the London Midland and Scottish Railway, read a paper to the Newcomen Society in London on October 12 entitled "George Jackson Churchward, Chief Mechanical Engineer, Great Western Railway: The Man and His Work." Extracts from his paper are given below.

George Jackson Churchward was born at Stoke Gabriel on the River Dart, Devonshire, in 1857. His father was the Squire of Stoke Gabriel, so there is no doubt as a boy he enjoyed plenty of opportunities for fishing and shooting and so laid the foundation for the hobbies which stood him in good stead in his busy mature life. He early showed an interest in mechanical devices and enjoyed making things. In 1873, he went to Newton Abbot as a pupil to John Wright, the Locomotive, Carriage and Wagon Superintendent of the South Devon, Cornwall and West Cornwall Railways.

At this time Richard Neville Grenville was also a pupil at Newton Abbot and between them they designed and built one of the first motor cars. It was a three-wheeler and the single wheel in front was tiller steered. They used a small Merryweather fire-engine boiler to provide steam and designed and built a steam engine to drive it. This was before 1876 and I believe it still exists in the possession of Allans of Oxford. In 1876 the South Devon and Cornwall Railways were absorbed by the Great Western Railway and Churchward went to Swindon to serve the last years of his pupilage, and then to the drawing office in 1877.

HOT BOXES

Churchward was engaged on the design of plant for the Severn Tunnel Pumping Station at Sudbrook, and no doubt when he was on the South Devon and Cornwall Railways he saw and was familiar with many of the Cornish pumping engines, which probably had something to do with the installation of the very fine examples built by Harvey's of Hayle for the Severn Tunnel plant. In December, 1882, he was appointed Assistant Carriage Works Manager; and in 1885 he was appointed Carriage Works Manager. It was whilst occupying this position that he developed the O.K. axlebox for carriages. It is reported that when he was carrying out experiments with this box he was amazed with the reports his inspectors made as to the cause of hot boxes. They always blamed dirt on the bearings. Churchward took a Carr brake van out of service and drilled a hole through the floor and the corner of the axlebox and inserted a copper pipe with a funnel at the top and then arranged for it to work in a train from Swindon to London. During the journey he fed flour emery down the funnel and on arrival at Paddington told his inspectors to feel the box, which was quite cool; but of course the journal was more like an hour-glass than a journal.

In 1895, Churchward went to the locomotive works as Assistant Works Manager, and on the retirement of Samuel Carlton in 1895, became Locomotive Works Manager. He at once started modernising the machine shops by installing British and American machines more able to take advantage of the new tool steels that were gradually being introduced. In 1902 he succeeded Dean as Locomotive, Carriage and Wagon Superintendent, altered to Chief Mechanical Engineer in 1916.

The first thing that occupied Churchward's attention was the design of the valve gear for future engines, and in this connection he had a small stationary steam engine built embodying his ideas of what the valve distribution should be. In this engine he incorporated a valve gear which gave a much longer stroke to the valve and with greater steam lap. He satisfied himself that he was able then to get a much fuller opening to exhaust when the engine was notched up.

Churchward undoubtedly had a gift for selecting young men who were not only able, but were willing to carry out his ideas in actual practice. He selected Collett from the drawing office and made him assistant works manager, and put with him G. H. Pearson and J. W. Cross as junior assistants to carry out experimental and development work, and he had George Burrows in the drawing office to work out the designs.

In 1904 Churchward's attention was attracted by the results being obtained in France with the De Glehn four-cylinder compound locomotives running on the Nord line, and he persuaded the directors to purchase first one engine, No. 102, and then two more larger additions of the same class. They were 4-4-2 type and undoubtedly were doing very good work, and to make a fair comparison Churchward converted one of his 4-6-0 engines, No. 171, to a 4-4-2 wheel arrangement for the purpose of the trial. There were many features on the French engines which satisfied his critical appreciation of what was good and what was second-rate. As an example: the inside big-ends on the French engines became the standard design for his own four-cylinder engines which he built later. The bogie arrangement with its double compression-spring control, and supporting pads practically the full width of the engine, became the standard arrangement for bogies on the Great Western Railway, later on the London Midland and Scottish and now for the standard British Railways engines.

About this time, in 1906, Churchward saw particulars in the American technical Press of what was called the American semi-plug piston valve. He was so impressed with the design that he purchased the rights of manufacture in this country and obtained a pair of valves for trial. The design of this valve is such that the steam rings for maintaining steam tightness are expanded by steam pressure, when the regulator is open, to fit the walls of the steam chest, and are locked in position by means of locking rings which are also activated by steam pressure. As you can imagine, a valve of this kind took some time to get into proper production and the organisation for maintaining it was built up over a number of years. It has, however, given extremely good results in service on the Great Western Railway. Knowing the difficulties that were experienced in getting it properly installed on the Great Western, I refrained from introducing it when I went to the L.M.S. Railway, as by that time the simple narrow rings in the piston-valve heads gave quite good results.

After the trials of the French engines, Churchward designed and developed his own four-cylinder engine, but it was a simple engine and not compound, and in April, 1906, the North Star No. 40 was completed.

TAPER BOILERS

In 1907 Churchward, who was always an advocate of large-capacity boilers, built one of his four-cylinder engines as a Pacific class with a large boiler having a wide firebox. This put up the weight on each driving axle to 22½ tons, and for the whole of its life it was kept on services between Paddington and Bristol, and later in 1924 when the boiler required renewal, Collett re-designed it as one of the Castles, as it became more and more important to have engines of the same class working in standard links.

As I have already indicated, Churchward was very concerned with providing ample boiler capacity on his engines, and although the original standard No. 2 boiler fitted to the Bulldog, which was an enlarged Duke class, had parallel barrel and straight sides to the firebox plates, he soon found that these straight sides and the straight barrel gave circulation troubles, which reacted on the stays causing considerable boiler maintenance. During this period Pearson and Cross carried out a number of experiments to determine how the water circulated in the boiler in service conditions. Plugs fitted with vanes were put in the various parts of the boiler and it was soon found that the parallel barrel restricted the flow between the barrel and the water legs of the firebox. Churchward then designed a boiler with a tapered barrel; the barrel and throat plate were at the full diameter, giving the maximum space for water circulation between the barrel and the water legs of the boiler. The squareness of the firebox gave way to curved side plates and crown, and Churchward spent a great deal of time in developing the curvature of the side plates in order to obtain free circulation and minimum stay stress for the expansion of the firebox and casing.

About this time, Churchward had particulars of the work done by Professor Goss of Purdue University in America on locomotive testing, and was so impressed that he designed a similar sort of testing plant which he installed at Swindon. He was thus able to make certain tests on his locomotive on the stationary test plant and confirmed these tests on the road with the dynamometer car. One of the things that interested him in Professor Goss's report was the test he carried out in connection with smokebox and blast-pipe design. Churchward carried out a similar series of tests on his engines and from these tests developed the standard smokebox arrangement which was used on all his engines and which was one of the reasons for the free running and good steaming generally of the Great Western engines.

He gave early attention to the principle of superheating, and in 1906 fitted up one of the 4-6-0 two-cylinder engines with a Schmidt superheater, and in 1907 one of the four-cylinder Star class was fitted with a Cole superheater. As a result of tests made on these engines he eventually developed the Swindon superheater, having two rows of elements, but having 1in. diameter tubes instead of the 1½in. of the other superheaters. One of the things he realised was that with the larger diameter tubes the core of the steam was not superheated at all and tended to dilute the mass of steam being delivered to the cylinders. Although he had a less number of rows of superheater units, I think it can be said that they were more efficient than the more conventional superheater. It cannot be said that the Great Western engines obtained high temperatures from the superheater, but Churchward was satisfied if he ensured the absence of condensation in the cylinders.

When he retired in December, 1921, the men in the works wished to make him a presentation; on being approached he told them he did not want anything, but on being pressed to accept something he asked for a fishing rod. Practically the whole of the staff in the works contributed to the presentation, and he was presented with a fishing rod at a mass meeting in the Mechanics Institute. The chairman of the Works Committee gave a very eulogistic account of how the men appreciated him as a chief and wound up by hoping that every hair on his head would be a candle to light him to glory. The old man, who was as bald as a coot, turned round and said "There won't be many of them, Watkins."

In 1933, he was killed while inspecting the line which ran alongside his garden, because he had noticed what he thought were slack places in the sleepers. Unfortunately, in the latter years of his life he was deaf, and suffered from glycoma in his eyes, so he did not realise that one of the fast trains to Wales, running late, was approaching. He was knocked down and killed on December 19, 1933, mourned by all his men.

So ended the life of the most progressive locomotive engineer of his time.

Letters to the Editor

EXTENSIONS TO RAILWAY RESEARCH

The New Testing Track

SIR, The leading article in your issue of October 7, "A Smoother Run," may perhaps convey to some readers the unintended impression that the British railways have hitherto paid little attention to the scientific investigation of the interactions between vehicles and track, and that the study of such problems by a research team is as notable an innovation as the Transport Comission's decision to construct a testing track. In fact, however, it would be nearer the mark to regard the proposed new testing installation as an improved weapon for which the most cordial welcome will come from railway research workers who have been obliged, in the past, to conduct their large-scale observations and tests under conditions that often were either unrealistic or far from perfectly controlled, in the experimental sense of that term. Nevertheless, much constructive research was done, the work by the Great Western Railway on the riding of high-speed four-wheeled freight vans, mentioned in your leader, being an admirable example.

As regards the London, Midland and Scottish system, where a research department was established some 25 years ago, it is a fair statement that most of the major problems studied by the engineering and metallurgy divisions, in co-operation with the civil and mechanical engineers, have been concerned with some aspect of vehicle/track inter-relation. Among the earliest of these was an analytical study, by the late Mr. S. R. M. Porter, of the motion of a locomotive on curved track. The full-scale tests on the riding qualities of a modified design of bogie, referred to in your article, were supplemented in the railway laboratory by studies with a reduced-scale model of a wheel-axle assembly on rails, and (more profitably) by an elaborate series of full-scale experiments in which the transverse oscillations of carriage bogies, having wheels in progressive stages of wear, were recorded by high-speed cinematography for subsequent analysis. The ciné camera also contributed to the design of a successful shock-absorbing wagon for the carriage of fragile freight, and demonstrated that an unsuitably balanced steam-locomotive driving wheel could "bounce" up and down, thereby crippling the rail, when slipping at a critical high rate of revolution.

Other researches, aimed at safety, passenger comfort and economy, in various proportions, have been concerned with the reduction of rail and tyre wear, the defective performance and occasional service fractures of axles, tyres, locomotive frames, rails, rail fastenings and sleepers, and the general behaviour of the permanent way. Experimental or theoretical studies have been made of the pressure distribution in ballast and formation under dynamic loading; of the phenomena in a long stretch of continuously-welded track under repeated thermal expansion and contraction; of the springing and other design features of locomotive trucks; of the geometry of tyre and rail profiles conducive to flange climbing; and of the performance of automatic train control equipment. In recent years increasing attention has been paid to riding on curved track and to the standardisation of an optimum form of flat-bottom rail. In much of this engineering work, the associated metallurgical factors, and their influence on the economics of service life and maintenance, have played an important part and been kept prominently in mind.

From the foregoing, by no means exhaustive, list of subjects on which vehicle-and-track testing has already been carried out, it is clear that the new testing track will mark, not so much a belated start, as a development in an established tradition of railway research—albeit, as your leader rightly emphasises, an important and opportune development in view of the trend towards higher speeds with Diesel and electric motive power. Some of that importance derives from the fairly general, though not invariable, conclusion from past experience, that while purely theoretical studies of railway mechanical problems are of great value in demonstrating principles, pointing out directions in which improvements may be possible, and revealing the relative influences of the variable factors involved, their rigid conclusions are sometimes counsels of perfection that engineering or metallurgical testing proves to be economically or structurally impracticable under actual conditions of railway operation. For similar reasons, even the conclusions drawn from experiments on the new testing track will need, in many cases, to be confirmed by longer-term trials on the main lines, and often modified before they can be confidently accepted for widespread application.

It may safely be inferred that the railway research staffs already possess a fund of experience and information on which to draw for the design and conduct of experiments on the new test track. This, no doubt, is one reason for the decisions to operate the track by the railway Research Department, and to install it at the nearest suitable site to the Department's main laboratories at Derby. In addition to the necessary research, under more closely controllable conditions, into subjects already studied, the testing staff will have no lack of new problems when the modernised trains have had time to make their peculiar marks on the tracks. A variety of work can be expected, for instance, in connection with high-speed braking, automatic train control, transition curves and super-elevation, rail-joint design and noise abatement. Even such perennial troubles as rail corrugation and periodic side cutting of rails may at last be solved. It is to be hoped that, at least, the attack on them will be vigorously renewed.

Yours faithfully,
F. C. JOHANSEN.

Solihull,
Birmingham.
October 10, 1955.

* * *

SEALING RECIPROCATING SHAFTS

A Need for Understanding Laboratory Measurements

SIR, In my letter published in the issue of ENGINEERING of September 2, I queried certain friction data in respect of the "Hallprene" fluid seal as contained in an article dealing with that product which appeared in your journal on June 17.

At that time I expressed surprise at the fact that packing friction figures had been quoted without reference to ram diameters and, in the absence of guidance to the contrary, the reader was left with the impression that the percentage of available hydraulic power dissipated in friction loss for this packing is independent of ram diameter. I asked for clarification of this point, for I believe it to be only logical that this friction loss must vary inversely with ram diameter, the pressure being constant. Furthermore, I questioned the absence of any particulars relating to other important factors such as ram velocity, viscosity of pressure medium and surface finish of ram.

Whilst I was surprised at the form in which these friction data were presented, bearing in mind that it was claimed to constitute guidance for designers, I was far more surprised to read the answer to my letter signed by Mr. J. S. Jarvis of Hall and Hall, Limited (your issue of September 16), in which he referred me to Mr. T. F. Watson's letter published by you on March 11.

Having most carefully re-read Mr. Watson's letter, I find myself entirely at a loss to understand why reference has been made to it in relation to my queries. You will recall, Sir, that Mr. Watson reasoned that packing friction figures are virtually meaningless unless accompanied by a complete statement of the conditions under which those figures were obtained, and went on to argue that, even then, that data could find no practical application for it would be inconceivable that precisely the same combination of conditions would be encountered. Certain of the factors which control packing friction are individually capable of exerting a really profound effect upon the resultant figure and, therefore, figures quoted from laboratory experience could well prove dangerously misleading if an attempt were made to apply them in actual service.

Is it not clear that Mr. Watson's letter substantiates my case rather than satisfies my queries? Can I be alone in feeling confused about Mr. Jarvis's letter?

I should appreciate some elucidation of this apparent contradiction for I find Mr. Jarvis's letter rather disappointing.

Yours truly,
R. N. JOHNSON.

James Walker and Company, Limited,
Lion Works,
Woking.
October 12, 1955.

* * *

LIFTING BRICKS AND BLOCKS ON FORK TRUCKS

SIR, My attention has been drawn to the article with the above title which appeared on page 435 of your issue of September 23, and in which a fork truck attachment for lifting bricks and blocks is described. In the first paragraph you state that the forks are ". . . designed to fit any of the range of fork trucks produced by Conveyancer Fork Trucks, Limited . . ."

I would like to point out that I.T.D. Limited pioneered the introduction of the Bickerstaff brick-handling forks in this country in conjunction with R. H. Corbett and Company, Limited, and that the equipment can be fitted to several makes of fork truck; for example, it can equally well be fitted to the Stacatruc range.

Yours faithfully,
D. N. RUSH,
Public Relations Officer.

I.T.D. Limited,
95/99 Ladbroke-grove,
London, W.11.
October 11, 1955.

[*Editor's Note.*—Since the publication of the article referred to above, we have been informed that the name "Bickerstaff" should be spelt without the final "e" which appeared in the original material.]

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NEW GAS TURBINE FOR THE "AURIS"

SIR, I would like to draw your attention to a mistake that has been made in respect of remarks that I made in the discussion of Dr. Strang's paper at the British Association meeting at Bristol this month. Please refer to the last sentence of the fourth paragraph in the second column on page 452, September 30, relating to the Auris.

What I said was that the Auris had run continuously from this country to Curacao and back in a voyage of about twenty-four days each way, and the sentence should be: "A 5,000 b.h.p. gas turbine was being fitted in the same ship which would have an efficiency of, say, 25 per cent. and a fuel consumption 50 per cent. greater than that of an oil engine at the present time."

Yours faithfully,
S. F. DOREY.

Lloyd's Register of Shipping.
September 30, 1955.

PERSONAL

MR. E. T. JONES, C.B., O.B.E., M.Eng., F.R.Ae.S., principal director of scientific research (air) Ministry of Supply, since 1949, has been elected President of the Royal Aeronautical Society, 4 Hamilton-place, London, W.1, for the session 1956-57. He will take office at the annual general meeting to be held on May 10, 1956.

MR. E. M. JOHNSON has relinquished his position of chief engineer, plant department, Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester, 17, and has been appointed consultant to the chief electrical engineer of the company. MR. C. P. HOLDER, B.A., M.I.E.E., has been made chief engineer, large electrical machine department, and MR. H. I. WOOD, B.Sc., A.M.I.E.E., assistant chief engineer, turbo-generator engineering department. MR. R. H. KELSALL, B.Sc., A.M.I.E.E., formerly assistant chief engineer, industrial process control department, has been made assistant chief engineer (industrial process control) in the recently formed electronics department.

MR. T. B. PARKER, chief rubber technologist to Johnson & Phillips Ltd., Charlton, London, S.E.7, retired on September 30 after 54 years of service with the company. He has been succeeded by MR. W. S. PENN, B.Sc.

COLONEL A. DE CHIMAY, T.D., Assoc.I.C.E., Assoc.I.Mech.E., a managing director of Prior Stokers Ltd., Prior Works, 1-3 Brandon-road, York-way, London, N.7, has been appointed deputy chairman of the company.

MR. C. G. T. HYSLOP retired from his office of managing director of the Phosphor Bronze Co. Ltd., on October 19, but remains a director. MR. D. L. ROOME and MR. A. N. WORMLEIGHTON have been appointed managing directors of the company as from October 20. Mr. Hyslop has been appointed vice-chairman of Kent Alloys Ltd., and a director of Birfield Industries Ltd.

COMMANDER (E) J. A. BLOCKLEY, R.N.(ret.) has been appointed export sales manager of the Parsons Engineering Co. Ltd., Town Quay Works, Southampton, Hampshire, the latest firm to become a full member of Associated British Engineering Ltd.

MR. STUART L. M. BARLOW, A.M.I.E.E., M.Amer.I.E.E., has been appointed a non-executive director of the Electric Construction Co., Ltd., Bushbury Engineering Works, Wolverhampton.

MR. GORDON LLOYD NICHOLSON, B.E.M., A.M.I.Mech.E., M.I.Loco.E., district motive power superintendent, Stewarts Lane, Southern Region, has been appointed modernisation assistant to the general manager of the Scottish Region of British Railways.

SIR JAMES M. MCNEILL, K.C.V.O., C.B.E., M.C., F.R.S., deputy chairman and managing director of John Brown & Co. (Clydebank) Ltd., was elected President of the Shipbuilding Conference at the annual general meeting in London on October 12, in succession to MR. J. W. ELLIOTT, C.B.E., whose term of office has been completed. MR. J. A. MILNE, C.B.E., chairman and managing director of J. Samuel White & Co., Ltd., Cowes, was elected vice-president.

MR. E. J. JEFFERIES, B.Sc.(Eng.) A.M.I.Mech.E., Parkstone, Dorset, has accepted an appointment, for a period of one year, from the United Nations Technical Assistance Administration, to give expert assistance in Mexico. The appointment has been made at the request of the Mexican Government and Mr. Jefferies will serve as Chief of the Mechanical Services Section of the Central American Research Institute for Industry.

MR. C. P. NICHOLSON has been appointed to undertake the direction of the North-Eastern area office of Metalock (Britain) Ltd., which is at Room 28, Third Floor, Exchange Buildings, Quayside, Newcastle-upon-Tyne, 1. (Telephone: Newcastle 24808.)

MR. TOM MURPHY has been appointed representative of the Stanton Ironworks Co., Ltd., in North-Eastern England. His address is 22 Queensway, Brunton Park, Gosforth, Newcastle-upon-Tyne. (Telephone: Widenpen 511.)

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COMMERCIAL

REDFERNS (BREDBURY) LTD., a subsidiary company of REDFERN'S RUBBER WORKS LTD., Hyde, Cheshire, has now commenced trading as a separate entity and all communications should now be addressed to Redferns (Bredbury) Ltd., Bredbury, near Stockport. (Telephone: Woodley 2687.)

SERCK RADIATORS LTD. and SERCK TUBES LTD. have together opened new offices at 16 Berkeley-street, London, W.1. (Telephone: MAYfair 9744.) This is to serve the interests of both main manufacturing companies in Birmingham. London area service for the motor-car industry for radiator, lamp, grille and bumper repairs is provided by the Serck London branch factory at Park Royal. (Telephone: ELGar 6041.)

HEAD, WRIGHTSON & CO. LTD. announce the formation of the HEAD WRIGHTSON EXPORT CO. LTD. to extend their interests in markets overseas. MR. VAUGHAN PENDRED has been appointed managing director with London headquarters at 20 Buckingham-gate, S.W.1.

TEDDINGTON AIRCRAFT CONTROLS LTD. have concluded an agreement with GIANNINI LTD., the British affiliate of G. M. GIANNINI & CO. INC., of New York and Pasadena, U.S.A., for the manufacture and marketing of Giannini pressure transducers, accelerometers and potentiometers, and their development to meet the specific requirements of British industry.

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CONTRACTS

Passenger Lifts. A further contract for 150 passenger lifts for housing estates has been placed by the London County Council with the EXPRESS LIFT CO, LTD. Each lift is capable of carrying eight persons, and the value of the contract is £386,020. Ninety-eight of the lifts will have automatic push-button control; pressure on a button will call the lift, provided that it is not in use. Thirty-six lifts will have full automatic collective control in which all calls, made by operating push buttons, are registered in the controller whether the lift is in use or not, and are dealt with automatically. The remaining 16 lifts will be interconnected in pairs and have the same fully-automatic collective control. As they are interconnected, however, there will be only one set of buttons on each landing common to the two lifts and the controller will automatically share the work between the two cars in such a manner as to reduce the actual journeys and waiting time to a minimum. In all the lifts the operation of the car and landing doors will be completely automatic, both being opened and closed by an electric door operator without any action on the part of the passenger. The doors, moreover, are to be fitted with sensitive edges which will cause them to reverse immediately if they should meet any obstruction when closing. The cars and the doors will be made of fluted aluminium having a natural finish. The whole of the equipment for the lifts, with the exception of the motors which will be manufactured by the parent company, the GENERAL ELECTRIC CO. LTD., Magnet House, Kingsway, London, W.C.2, and the T steel guides and wire ropes, will be made at the company's Abbey Works, Northampton.

Power-Station Plant and Equipment. During September contracts were placed by the Central Electricity Authority for power-station, transforming-station and transmission-line equipment, amounting in the aggregate, to £17,151,830. The principal contracts include: for Marchwood power station, near Southampton: two 30,000 lb. per hour auxiliary boilers, with JOHN THOMPSON WATER TUBE BOILERS LTD. For Poole power station: a 340,000 lb. per hour boiler, with INTERNATIONAL COMBUSTION LTD. For Staythorpe "B" power station, Newark: two 550,000 lb. per hour boilers, with BABCOCK & WILCOX LTD. For Willington "A" power station, near Derby: 275 kV, 7,500 MVA switchgear, with the BRITISH THOMSON-HOUSTON CO. LTD. For Rogerstone power station, Monmouthshire: two 60,000 kW turbo-generators, condensing and feed-heating plants, with C. A. PARSONS & CO. LTD.; two reinforced-concrete cooling towers, with FILM COOLING TOWERS (1925), LTD.; and one chimney, with J. L. KIER & CO. LTD. For Sittingbourne substation: 132 kV, 2,500 MVA switchgear, with the ENGLISH ELECTRIC CO. LTD. For Ellesmere Port substation: 132 kV, 3,500 MVA, switchgear, with FERGUSON PAILIN LTD.; for Dickinson-street substation, Manchester: a 60 MVA, 132/33 kV transformer, with FERRANTI LTD. An 132 kV overhead transmission line between Fleet and Pyestock, with BALFOUR BEATTY & CO. LTD. 33 kV and multicore cables for Great Yarmouth, with PIRELLI-GENERAL CABLE WORKS LTD. For Willington substation: a 275 kV twin 0·4 sq. in. overhead line, with WATSHAM'S LTD.

Hydrogen Plant. THE POWER GAS CORPORATION LTD., Stockton-on-Tees, have received an order from Laporte Chemicals Ltd. for a Hercules plant to produce high-purity hydrogen. The plant will comprise a reforming furnace, CO conversion and CO_2 removal equipment, with methanation, and a Wiggins gasholder.

NON-ENGINEERING INDUSTRIES

Opportunities for Engineers

Readers of ENGINEERING cannot be unaware that there is at present a shortage of high-class technical manpower; or that there is a risk of that shortage becoming more acute in a world where, as Sir George Nelson has pointed out, a growing population and increasing demand will necessitate greater economy being exercised in the use of our natural resources. A similar shortage may also have to be faced further down the ladder of employment, to overcome which, as Mr. W. Bamford rightly argued in his address to the Measurement and Control Section of the Institution of Electrical Engineers last week, it will be necessary to apply both existing and new techniques in hitherto untried situations, thus leading to the use of machines which can be left to operate with the minimum of attention. This will, however, require the employment of more men and women on fundamental research and development work and especially on the application of the results of their investigations to practical purposes. How the necessary recruits are to be found is a problem which is, of course, common to engineering as a whole and not solely to the electrical branch.

In this connection an interesting point arises. While both Sir George and Mr. Bamford confined their remarks to the need for engineers and technologists within the electrical industry, Mr. D. B. Hogg, in an address to the Utilisation Section of the Institution of Electrical Engineers which was also delivered last week, discussed "the opportunities, responsibilities and recruitment of professional electrical engineers in industries other than the electrical." In doing so it must be admitted that he made out a good case for a course which at first sight may look a little like desertion. He recommended the young electrical engineer to consider the wider world where electrical engineering was only an adjunct to the business of making and selling something else; and pointed out in glowing terms how such a course might lead to wider interests and accelerated promotion. He made the further point that the problems encountered "in other industries" covered such a wide field that the electrical engineer in time attained a useful knowledge of many things of a non-electrical nature; and that was good both for him and for industry generally.

Mr. Hogg added, in support of his thesis, that the well-educated and intelligent engineer "looking at an old trade from the fresh angle of his training and scientific background, should be able to sort the wheat of inherited skills and know-how from the chaff of dead custom and inertia," and to "persuade his employers to use modern science and engineering to the betterment of the product and enrichment of everybody concerned." It will, be generally agreed, that a closer connection between the maker and user of engineering equipment of all kinds is highly desirable. An electrical engineer engaged in a steelworks is, for instance, in a position to offer useful suggestions for improvement in the design and production of the equipment in which he is primarily interested and thus to provide a system of "feed back" the value of which can hardly be overstressed.

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DIVIDING ENGINES

Science Museum Display

An exhibition to illustrate the evolution of the dividing engine was opened at the Science Museum, South Kensington, London, S.W.7, on October 1 and will continue to be on show during the coming six months.

Eight circular dividing machines are on exhibition at the museum, ranging in date from 1778 to 1955, and two of them are shown in operation.

THE IRON AND STEEL INSTITUTE AT SCUNTHORPE

A special meeting of the Iron and Steel Institute was held in Scunthorpe from Wednesday, October 12, to Friday, October 14, at the invitation of the President and Council of the Lincolnshire Iron and Steel Institute. The meeting opened on the morning of the first day in the Drill Hall, Cottage Beck-road, Scunthorpe, when Lt.-Commander (E) G. W. Wells, R.N.(ret.) D.L., M.I.Mech.E., President of the Lincolnshire Iron and Steel Institute and a director and general manager of the Appleby-Frodingham Steel Company, occupied the chair.

Welcoming the visitors, Lt.-Cmdr. Wells said that it was the first time that a special meeting of the Iron and Steel Institute had been held in Scunthorpe, and it was 22 years since a visit had been made by members who had come over for a day from a meeting held in Sheffield in 1933.

Many of the advances made in fundamental techniques of iron and steel manufacture had taken their rise in the Scunthorpe area. For example, the first hot-metal tilting open-hearth furnaces in Europe had begun operation in Frodingham in 1902, and the first mechanically-charged blast-furnace—No. 4 at Frodingham—had been blown in in 1905. It had been at Normanby that the use of mixed blast-furnace and coke-oven gas had been first introduced to the industry, in 1927, and the general principles of integration of the gasholder as a link between ironworks and steelworks had been established.

Furthermore, the first under-jet coke ovens had been built in this area and, in rolling-mill engineering, the first mechanical cooling bank and mechanical straightening plant for heavy sections had been introduced in 1936. In more recent times flying shears had been introduced to a large billet mill.

In ironmaking, the Scunthrope area had seen the adoption of ore-bedding plants, carbon hearths and the large-scale introduction of 100 per cent. self-fluxing sinter practice.

In returning thanks, the President of the Iron and Steel Institute, Sir Charles Bruce-Gardner, referred to the urgency of continued research and development. Much had been done since the war and the British steel industry and other industries could show a really fine record.

Pig iron, continued Sir Charles, had first been produced by the old Frodingham Iron Company in 1866. On the steelmaking side, only two 20 ton steel furnaces were in production at the end of the 19th century and the output was then 650 tons a week. In 1913, the output of iron ore in Lincolnshire had risen to 2,640,000 tons. By 1954, the production of ore had become 5,500,000 tons and the output of steel 2,000,000 tons.

SIR ROBERT HADFIELD MEDAL

On being called upon, the Hon. R. G. Lyttelton, past-president, Iron and Steel Institute, presented the Sir Robert Hadfield Medal for 1955 to Mr. T. F. Holmberg, of Finland. In doing so he stated that the medal had been awarded to Mr. Holmberg for meritorious service in the production of iron and steel in his native country. In a brief reply, Mr. Holmberg thanked the President and members for the honour conferred upon him.

The meeting then turned its attention to the presentation and discussion of technical papers and this and subsequent sessions will be dealt with in future issues.

In the afternoon, visits were paid to the Appleby-Frodingham Steel Company; John Lysaght's Scunthorpe Works Limited; the Redbourn Works of Richard Thomas and Baldwins Limited; Thos. Firth and John Brown, Limited, and the Dragonby ironstone mine of the United Steel Companies Limited. These same works were visited by parties of members on the afternoon of Thursday, October 13 and on the morning of Friday, October 14.

In the evening a reception and buffet supper were held at the Baths Hall, by invitation of the Mayor and Corporation of Scunthorpe.

(*To be continued*)

AUTOMOBILE RESEARCH

Cylinder Wear, Fuels and Lubricants

Following tradition, this year's chairman of the automobile division of the Institution of Mechanical Engineers, Dr. C. G. Williams, in his chairman's address given on October 7, drew on his personal experiences. He is now the Director and General Manager of Shell Research Limited, but began his career with the Research Association of British Motor and Allied Manufacturers—a body formed soon after the 1914-18 war, and whose direct descendent is the Motor Industries Research Association of to-day.

Dr. Williams said that his first three years were devoted to carburation studies—a work which occurred again many years later at the Thornton laboratories, particularly in regard to mixture distribution in aero engines. About 1928 the problem of wear came to the fore and studies continued for some years. At that time each worker was expected to make his own abstracts from technical literature, which in Dr. Williams's view enabled them to pick out the gist of an article and also improved report writing.

In 1931 R.A.B.M.A.M. was wound up and the assets and activities transferred to the Institution of Automobile Engineers. The work grew and in 1936 was moved from the original site of Chiswick to bigger accommodation at Brentford. One of the main difficulties in arranging the research programme was to cover a sufficiently wide range of problems to maintain the interest of a diverse clientele. One of the most important techniques achieved was that of temperature measurement and the determination of the effect of temperature formed a large part of the work for many years. This included brake-fade and drum-heating, and the effects of temperature on bearing life and loading.

Work on wear continued steadily with a long programme to determine the causes. Dr. Williams said that many variations were tried until the cyclic test showed the effect of cool cylinder walls, and condensation. The problem of cylinder wear was still to the fore although not as serious as formerly, and is being combatted by the oil companies by the use of additives. Methods using radio-active piston rings had been developed for giving a continuing picture of wear rate. Other durability studies were concerned with valves and gears and there was also work on fatigue failures (particularly Diesel crankshafts) and extra-mural research at Ricardo and Company, Limited, on lubricating oil consumption.

In 1940, Dr. Williams said he moved to the new Thornton laboratories of the Shell Petroleum Company and work then was at first concerned with the assessment of fuels and lubricants. Petrol injection also came under intense study. Dr. Williams said that as the organisation grew, his duties became more and more confined to the administrative field and he therefore only intended to give a general account of current studies. He described the viewpoint of an oil company and how the laboratory work had to cover a wide field. In particular, it was the interrelation of all the different parts of an engine which together made the whole. Quality and suitability of fuel, freedom from engine defects and combustion efficiency formed one group of studies and lubricating oils formed another large section. Dr. Williams, in speaking of test procedures, mentioned the danger of basing too much on accelerated tests. It was always possible that conditions may be too far distorted (by increases of temperatures, for example) to give a true comparison to normal operation.

* * *

RAILWAY PRODUCTIVITY

Annual Dinner of the Institution of Production Engineers

The President of the Institution of Production Engineers, Sir Leonard Lord, K.B.E., was in the chair at the annual dinner held in London on October 10. In proposing the health of the guests, he dwelt on the important part the production engineer had to play in shaping the future of industry. With the rising costs of materials, attention to detail was vital. He wondered whether automation had not been rather oversold and urged that a strict sense of proportion should be maintained.

The response, given by Sir Brian Robertson, G.C.B., chairman of the British Transport Commission, was mainly concerned with railways, in which substantially increased production efficiency was a necessity for survival. Much of the delay and many of the difficulties were due to shortage of staff, particularly shunters, guards and firemen. Unfortunately, the railways could not restrict their output to suit the number of men available. In view of this, and of the recruiting difficulties, Sir Brian went on to say that the only solution was to get more per man, which could be done in three ways. The first was the elimination of redundancy, which had almost been done. Secondly, the equipment and its method of application should be improved. One signal box must do the work of six, one marshalling yard the work of four, and one Diesel locomotive haul as many trains as previously needed two or three engines in steam. Sir Brian said that these figures were not exact, but were a good indication of what was needed. It was intended to install electronic equipment for recording, sorting and tracing freight wagons, which might well prove to be the biggest single contribution to efficiency. Thirdly, operating methods must be recast to make the best possible use of the plant and staff.

At the conclusion of the evening five Institution awards were presented. These were: the Viscount Nuffield paper 1954, to Major-Gen. W. A. Lord, C.B., C.B.E.; the George Bray Memorial Lecture, 1954, to Mr. Robert Douglas, M.B.E.; the Institution Medal for the best paper by a member in 1953/4, to Mr. K. J. Hume; the Institution Medal for the best paper by a non-member, to Mr. F. Nixon; and the Hutchinson Memorial Award, 1953/5, to Mr. G. Cubitt-Smith.

* * *

METHANE IN COAL MINES

Danger of a Falling Barometer

A warning to take additional precautions against explosive gases, particularly methane, in coal mines when the barometer is falling is given in a report recently issued by the United States Bureau of Mines. The report describes a study made in an Illinois coal mine that proved when the barometric pressure drops, gas feeds into adjacent airways, both from sealed and unsealed abandoned workings. It was found that the methane content of the air exhausted from the mine ranged from 0·5 per cent. during periods of high barometric pressures to as much as 1·5 per cent. when the pressure was low.

The report, R.I 5147, *Effect of Changes of Atmospheric Pressure on Gas Emissions from Worked-out Areas in an Illinois Coal Mine*, can be obtained from the Bureau of Mines, Publications—Distribution Section, 4,800 Forbes-street, Pittsburg, 13, Pa., U.S.A.

Book Reviews

FOOD FOR THE MILLIONS

Land, Water and Food. By HERBERT ADDISON, O.B.E., M.I.C.E., M.I.Mech.E. *Chapman and Hall, Limited, 37 Essex-street, London, W.C.2.* (18*s.*)

In his presidential address to the British Association in 1898, Sir William Crookes predicted that, as population increase was overtaking food production, a state of widespread world hunger would have set in by 1930 unless food yields rose steeply. In 1898, the wheat acreage in Canada was 4 million; in 1930 it was 27 million. As a result of this and other developments, Western nations continue to be adequately fed. In some Asian countries, however, although the present condition can hardly be described as one of world hunger, malnutrition and low standards of living are widespread.

The World Food and Agriculture Organisation has estimated that world population is increasing at the rate of 20 million a year. To feed the increasing population it is clear that food production must increase as fast, or faster, unless there is to be widespread famine with its concomitant horrors of disease and pestilence. It is also clear that the increase in food supply is to a considerable extent responsible for the rise in population. The population of Canada would not have increased as it has, had food production not increased *pari passu*. This is realised by Professor Addison and in the course of this level-headed book, referring to the fact that the population of Egypt rose from 5 million in 1870 to 20 million in 1950, he expresses the opinion that, had the many control structures on the Nile not been built, the population to-day would have been much less than it actually is. The book is a wise and restrained contribution to the world food problem. Interesting accounts are given of what has been done, and is being done, in connection with river control and irrigation in England, Holland, Italy, Egypt, the Levant States, India, Australia and the United States, typical examples being chosen in each case, and reasons for failure in some cases, as well as success in many, being clearly explained.

The descriptive matter in the book is not of a highly technical nature and it should appeal to the educated general reader. Professor Addison states that his book is descriptive rather than speculative; that is perhaps its particular value in connection with a matter on which enthusiasm is inclined to outrun knowledge. As it is aptly put in the concluding section, those who glibly talk of irrigating the desert may well be asked "which desert?" and "with what?" It is not suggested that there may not yet be room for further extensive developments but it is asserted that "of the estimated increase in world food production required during the next half-century, not more than one-fifth of this total can be expected as a result of new large-scale engineering works."

The above remarks must not be taken to indicate that the book is solely concerned with the more spectacular works of the civil engineer. The small-scale activities of the individual cultivator are fully dealt with and the reasons for his success or failure explained. Food production is not only a social question; it is an economic one. The most attractive activities, aimed at adding to the total food supply of the world, will not endure if they are economically unsound. There are regions in which crops may be raised in a good year but in which rainfall is so erratic that two bad years may follow a good one. It is pointed out that, in some such cases, a permanently successful regime may be established by storing food rather than attempting to store water. One million three hundred tons of water are required to produce three hundred and twenty tons of food on one square mile of land. Another possibility with semi-arid lands, which has already been to some extent exploited, is the development of resistant varieties of food plant.

BOOKS RECEIVED

Some of the books noticed here are selected for extended review in ENGINEERING.

Industrial Democracy: A Revaluation. By W. H. SCOTT. University of Liverpool, Department of Social Science, Occasional Papers No. 2. *Liverpool University Press, Bedford House, 75 Bedford-street South, Liverpool,* 7. (3*s.* 6*d.*)

This booklet stresses that changes in the legal or formal responsibility for policy decisions in industry are not desirable at the present time, but it is emphasised that management-shop steward procedures should be systematised to allow regular discussion of all matters of common concern. Emphasis is also laid upon the importance of the development of "consultative leadership" at all levels of the firm, as a prerequisite of more effective procedures at the policy level. In a concluding section, the steps which are necessary to achieve this are discussed. A leading article on this subject was published in the issue of September 16.

Form Design. A Report Produced by an Organisation and Methods Study Group of the Office Management Association. *Office Management Association, 58 Victoria-street, London, S.W.*1. (6*s.*)

In preparing this book, the Office Management Association is reiterating the opinion of its members that, if forms are essential, they should be properly designed for the purpose. The publication has been directed more towards the industrial and commercial community, but is intended for all who are striving after economy in administration. The book is divided into three sections covering introduction and the approach to the problem, design in relation to the use of the form and design in relation to the production of the form. The text is illustrated with diagrams of forms for various purposes.

The Education and Training of Graduate Staff for Industrial Research. Report of the Conference at Ashorne Hill, 1955. *Federation of British Industries, 21 Tothill-street, London, S.W.*1. (4*s.*)

The Conference was divided into four sessions in which papers were presented respectively on "Staffing and Managing a Research Department"; "First Degree Courses in Science and Technology at the University"; "The Selection and Training of Graduate Research Staff in Industry"; and "Post-graduate Training at the University." With the exception of the first section, the papers, with a summary of their ensuing discussions, are reproduced in this report. A list of members of the Conference is given at the end of the report.

Diesel Engines. Case Study Data on Productivity and Factory Performance. Bureau of Labor Statistics Report No. 86. Prepared for the Foreign Operations Administration, Office of Industrial Resources, by the United States Department of Labor. Distributed in Great Britain by the *British Institute of Management, 8 Hill-street, London, W.*1. (10*s.*)

The book commences with a general report and follows this with detailed case studies of five plants. There are 42 statistical tables covering all aspects of Diesel engine manufacture and three appendices. This series of reports is not intended to give novel information, but to supplement material from other sources.

Electrical Accidents and their Causes, 1953. Ministry of Labour and National Service, Factory Department. *H.M. Stationery Office, Kingsway, London, W.C.*2. (3*s.*)

This report is divided into three sections: accidents, analysed statistically; occurrences in connection with electricity supply; and in industrial applications. Since the aim of these reports is to draw attention to dangerous situations so that they may be rectified, it is disappointing to observe that there has been no decline in the number of reported accidents since 1947, and the number of fatalities is the highest since 1944. Actual examples of each type of accident are quoted and there is a long section dealing with safety precautions for industrial equipment.

National Wages Policy. By JAMES DRISCOLL; and **The Audience of Politics.** By GEORGE ENGLE. *The Bow Group, 30 Pall Mall, London, S.W.*1. (2*s.*) (The former was reviewed on page 489, in the issue of October 7.)

Steam Road Vehicles and Rail Cars in Germany. Compiled by J. N. WALTON. "*Light Steam Power*," *Kirk Michael, Isle of Man.* (3*s.* 6*d.*)

The material for this booklet is based on information obtained by British Intelligence services. It deals with the products of five firms, and includes many post-war models. Post-war development of steam transport was encouraged in Germany due to the lack of liquid fuels, and it is interesting to note that the fuel cost of running an 8 to 10 ton steam vehicle is only one-eighth that of a similar petrol-driven lorry. The vehicles described include lorries, buses and rail-coaches, and performance figures are given.

Medicine Creek Dam: Technical Record of Design and Construction. *United States Department of the Interior, Bureau of Reclamation, Denver, Colorado, U.S.A.* (No price given.)

Medicine Creek Dam is located in south-western Nebraska, and was built in 1948–1951, as part of the Missouri River Basin Project. The purpose of construction was to regulate the waters of Medicine Creek for flood control and irrigation, and the Cambridge unit of the Missouri River Basin Project will derive its water supply entirely from water stored in the reservoir. This book is a record of the design and construction of the dam, and is well illustrated with drawings and photographs. Appendices give details of tests and costs of the dam, and references to other Bureau of Reclamation reports on the same subject.

Das Genauigkeitswesen in der technischen Normung. By JOHANNES ICKERT. Part 4 of Wissenschaftliche Normung. *Springer-Verlag, Reichpietschufer 20, Berlin, W.*35. (8.40 D.M.)

"Accuracy in Technical Standardisation" is the fourth number in a series on scientific standardisation brought out in conjunction with the Training College for Technical Standardisation at the Hanover Technical University. Although the opinion is expressed that every standard should be "accurate" in the sense that the norm is specifically expressed, the question still remains open as to when further directions regarding the degree of accuracy must be explicitly given for individual dimensions. It is the purpose of this book to investigate where the need arises for tolerances, how and to what extent they must be provided for and to show that an individual system of standardisation can affect the issue as a whole. The general principles of the theory of accuracy are given and the features important for standardisation are emphasised. The knowledge thus acquired is then applied to standardisation and at the end of each section the results, which are essential from the technical standardisation point of view, are set out in the form of fundamental principles to be borne in mind. Treatment of the subject is such that it would interest technologists concerned with standardisation and in particular the engineering branch where limits and fits are important.

Probleme der Plastizitätstheorie. By WILLIAM PRAGER. *Birkhäuser Verlag, Basel/Stuttgart.* (12.50 D.M.)

This book dealing with problems of the theory of plasticity is based on a series of lectures given by the author in Zürich at the end of 1954. Its main purpose is to create an intuitive understanding of the singularities of plastic behaviour, whilst numerous literary references provide opportunities for the technologist to extend this knowledge by further study. The first chapter is concerned with the mechanical behaviour of plastic solids. Dynamic models of the perfectly elastic, the rigid perfectly plastic, and the elastic perfectly plastic solids under uniaxial stress are described and the relation between stress and strain rate in a rigid, perfectly plastic solid under uniaxial stress is established. The second chapter is devoted to the mechanical behaviour of structures in the plastic range. Extremum principles are formulated and the concepts of load carrying capacity and shake-down are discussed. Chapter three contains methods of determining the load carrying capacity of various types of rigid, perfectly plastic structures (limit analysis) and the fourth chapter deals with finite plastic deformations, the theory of plane plastic flow being discussed in some detail. The text is illustrated by diagrams and it is stated that the majority of the problems dealt with have originated in technical literature during recent years and are now treated for the first time in book form.

Getriebelehre: Eine Einführung. By KARL POLACZEK. *Carl Hanser Verlag, Leonhard-Eck-Strasse 7, München 27, Germany.* (4.80 D.M.)

This booklet is an introduction to the subject of kinematics. A number of problems are set so that readers who have studied the text can acquire experience in the application of the principles involved. The theory of motion which forms the basis for the desired course of action of machinery is dealt with. Facts are stated concisely and formulae and diagrams are provided to show the method of calculation and the nature of the movement concerned. The main features are: plane motion; ascertaining the speed of individual points; crank drive; acceleration; slide crank drive; cams; and straight-guide movements.

AN INTRODUCTION TO REACTOR TECHNOLOGY

DESIGNING A GAS-COOLED POWER-PRODUCING PILE

Descriptions of particular nuclear reactors and reactor schemes have already appeared in ENGINEERING, *but so far little has been written in general concerning the problems of reactor design. This subject was discussed in a paper entitled "The Design and Operation of Power Producing Reactors," and presented before a meeting of Section G of the British Association on Friday, September 2, by Mr. H. H. Gott of the United Kingdom Atomic Energy Authority Industrial Group, Risley, Lancashire. A discussion of the paper was reported in* ENGINEERING *on September 23 (page 417). In his paper, which served as an excellent introduction to reactor technology, Mr. Gott outlined various factors which have to be considered in designing power reactors and indicated the approach required for this work. "The reactor engineer," he said, "has to develop a characteristic style in his thinking which is somewhat different from that of his fellow engineers who specialise in other fields." Mr. Gott also emphasised that the paper necessarily simplified the subject and had been "framed with the sole object of describing, or rather hinting at, the types of technical problem encountered, rather than the solution to these problems." The author's purpose was thus to show the kind of decision which has to be made before a project can proceed, and, in addition, to underline the need for broad knowledge rather than narrow specialisation. In attempting this he has considered in particular the gas-cooled graphite-moderated pile. Installations of this kind have previously been described in* ENGINEERING, *together with diagrams, in vol. 177, page 313 (1954) and in vol. 179, page 240 (1955). The following article is an abridged version of the paper.*

FAST AND THERMAL REACTORS

There is considerable debate concerning the most suitable type of reactor to develop for power production purposes, and the controversy covers both nuclear characteristics, and also the engineering question of heat extraction. Power-production in this case means large-scale generation of electrical energy as part of a grid distribution system, with particular application to this country.

So far as the physics is concerned, there are two kinds of reactor to consider. The first includes those in which the neutrons spend their brief lifetimes in the reactor moving as fast as may be arranged—the so-called fast reactors. These appear to offer such advantages in low neutron losses that they can turn uranium 238 or thorium atoms, which are not normally very useful as fissile materials, into plutonium or uranium 233 with so high an efficiency as to operate with an overall profit in fissile material. For this reason they are also known as breeder reactors. Reactors of the second type, by contrast, have their neutrons travelling as slowly as conveniently possible. They are the slow-neutron or so-called thermal reactors, which have the advantage of operating with a very much lower concentration of fissile material. Because of this they run on a much cheaper fuel, and it is therefore economical to extract heat at a correspondingly lower rating.

Of the various possible methods of extracting heat, such as the use of liquid metals, water, heavy water, or gas as coolants, only one will be dealt with here, namely gas cooling; but that will be sufficient to illustrate all the points which will be considered. The gas-cooled reactor will therefore form the basis of this article. This choice has the advantage that we now know how to design and construct a reactor of this kind, which will be an economic proposition for control power station work. This does not mean that other designs cannot be developed successfully, but it is fair to say that the problems to be solved for the different systems vary widely. In the case of the gas-cooled reactor they are engineering problems which we have some experience in tackling, and these will be described in general terms.

An example of a gas-cooled reactor power plant is that being built at Calder Hall. This project has been studied in detail by the design teams set up by industry to put forward proposals to the Central Electricity Authority, and it is anticipated that it will produce electricity with a reliability and at a price comparable with the operation of coal-fired plants. A reactor of this type has, in principle, a comparatively small number of component parts. It contains uranium fuel, a moderator to reduce the neutron velocity, a cooling system to remove the heat from the reactor, a boiler plant to make this heat useful in a normal turbine house, a control system, and the necessary shielding against radiation to make the plant habitable and workable. There are also ancillaries of which perhaps the most interesting is the fuel-handling system.

STRUCTURE OF GRAPHITE BLOCKS

In general outline the reactor consists of a cylindrical structure of graphite blocks, some 25 ft. high, and about 40 ft. in diameter enclosed so that it may be cooled by a gas under a pressure of several atmospheres. At intervals of about 7 to 9 inches there are holes in this structure parallel to the axis of the graphite. They are the channels through which the coolant flows, and in which the uranium fuel is placed. The fuel elements are in the form of long rods covered with a metal skin or can. The cooling circuit comprises duct work to carry the gas to and from the boiler plant, and circulating fans or blowers, which keep the gas in motion. The power consumed in achieving this is quite appreciable and to keep it within reasonable limits the whole circuit is maintained under high pressure.

The reactor itself is surrounded entirely by a thick concrete shield designed to absorb practically all the radiation from it. Passing through this shield are large gas ducts, various leads for instruments, the reactor control gear, and the means for renewing the fuel in the reactor core after it has been sufficiently burned.

The mechanism of the chain reaction is well known, but it may be useful to recall certain of its features. The reactor core can be regarded as a lattice work of cells, each consisting of a uranium rod, the cooling channel around it, and its allocation of moderator. The operation of a reactor is made possible by the nature of the fission process. Whereas the fission of a uranium nucleus is caused by the arrival of one neutron, on the average a larger number of neutrons (actually about 2·6) is produced during the fission. After release from the disintegrating nucleus the neutrons have a very high velocity, and travel around within the reactor until they are either absorbed by something within it, or escape from the outer boundary of the core. In their travels, they encounter other nuclei, and in doing so lose energy.

FUEL AND MODERATOR

It is clearly desirable to use as cheap a nuclear fuel as possible and at present natural uranium fulfils this condition. This has about 140 times as much uranium 238 as uranium 235. Uranium 235 undergoes fission very much more easily than uranium 238, but the relative probability of a neutron being caught by uranium 235 and by uranium 238 varies considerably with the neutron velocity. The lowest velocity a neutron can attain while diffusing through the graphite moderator is that at which there is an equal probability of the neutron gaining or losing energy in collision with a carbon nucleus in the moderator. In fact the situation may be compared with the diffusion of a very hot gas through a cold porous solid—the gas molecules will reach thermal equilibrium with the atoms of the solid, after losing energy to it. In the same way, the energy lost by the neutrons is given up to the graphite moderator, and the neutrons may fairly be said to reach the same temperature as the moderator. During this process an amount of heat is released which is rather more than 5 per cent. of the total heat liberated in the reactor. This heat is removed by the same gas stream which cools the uranium.

PROFITABLE AND PARASITIC NEUTRON ABSORPTION

Although there is an apparent profit of 1·6 neutrons per fission, it is necessary to design a reactor so that these are used to best advantage. Of those caught by uranium 238, a few—known as fast neutrons—will cause fission, so helping to sustain the chain reaction, but by far the greater number will be absorbed, thereby ultimately producing a new fissile material, plutonium. Although this is of benefit in that fissile material burned is to some extent replaced by new material, it must be remembered that all neutron absorbing processes in the reactor are competitive. Uranium 235 has by far the greater neutron-absorption cross section for truly thermal neutrons, but this varies rather sharply with neutron temperature; at rather higher neutron velocities uranium 238 has a strong resonance band which can lead to excessive capture, and it is for this reason that fuel and moderator should be kept quite separate. In a homogeneous mixture of moderator and graphite the neutrons would be absorbed preferentially by uranium 238, and would never become thermalised; consequently the chain reaction would be quenched.

Uranium is by no means the only material to absorb neutrons. As has been stated an average of 2·6 neutrons are emitted each time a uranium 235 nucleus disintegrates, but of these only a proportion have so far been accounted for: one strikes another uranium 235 nucleus, causing fission and continuing the chain reaction, while a smaller fraction (between 0·5 and 1) is captured by uranium 238 to produce plutonium. The remainder will either be absorbed in other materials in the reactor, such as impurities in the graphite moderator, or in the metal cans round the uranium fuel, or they will be lost from the outside surface of the system. The larger the core, the less important is the surface effect; thus where neutron absorption within the core is very great, the reactor will only work if the core size is large.

CRITICAL SIZE FOR GIVEN LATTICE

The reactor designer has access to extensive tabulated information regarding the neutron absorption of all the materials concerned, while in addition, the rate of diffusion and slowing down of neutrons in graphite, and the effect of coolant channels of varying geometries have been studied experimentally. Thus it is not difficult in principle to calculate the behaviour of the system for a range of uranium rod sizes and spacings, for cooling-channels of different sizes and lengths, and for various thicknesses of canning material on the uranium bars. Here the main difficulty lies not so much in performing the calculations, as in presenting the information in a convenient form. This problem, which also arises in estimating the thermodynamic performance and heat-transfer characteristics of a system, is always present when a large number of variables are involved.

The results of these nuclear calculations may be given in terms of the critical size for a given lattice arrangement, or the excess neutrons formed in each generation compared with the previous one (the so-called reactivity of the system), or in terms of the uranium 235 concentration required for a system of given size to operate. There are some advantages for particular purposes

in each approach. As an example the influence of lattice pitch may be considered. Clearly, other things being equal, for a given size of pressure shell the more uranium cooling channels that can be incorporated the better, since the heat output would be higher and such capital items as pressure vessels and shielding would be more efficiently utilised. However, decrease in lattice pitch beyond a certain point will cause the system to be under moderated, and too great a proportion of neutrons will fall to the uranium 238; this problem would of course be simplified if it were possible to use graphite of higher density.

FUEL ELEMENT TEMPERATURE AND COOLING SYSTEM

Meanwhile, corresponding calculations must be made for the cooling system. A tentative figure for the maximum temperature at which the fuel may be operated is settled on the basis of experience with reactors of generally similar type, and also by reference to metallurgical research work. In general, during the design period, further experimental work will be carried out to investigate the soundness of the design fuel-element temperature, and if this has been wrongly chosen considerable revision of the design may be necessary. If this temperature is chosen too conservatively, a low coolant outlet temperature will limit the thermodynamic efficiency of the energy conversion cycle. If too high a temperature is chosen, some of the fuel elements may give trouble, leading to undesirably frequent shut-down of the system for discharging faulty elements.

There is some analogy here with the use of high-temperature alloys in gas turbines; here too, it is necessary to achieve an effective compromise between high operating temperatures and cycle efficiencies, and the reliability of operation over long periods which is associated with low temperatures.

When the maximum fuel-element temperatures have been chosen, arrangement must be made to ensure that the coolant leaves the reactor as close to this temperature as possible; that is, in heat-exchanger terms, the thermal ratio should have the highest possible value. In practice this means that a considerable quantity of extended surface on the fuel elements is required for heat-transfer purposes, and this is necessarily introduced at the expense of parasite neutron absorption. However, there is usually no point in increasing the heat-transfer surface indefinitely even apart from the neutron loss, since the heat releases involved are rather high, and temperature drops along the metal extended surfaces and in the uranium itself are correspondingly high. The demands for high heat output and high coolant temperature oppose one another unless a very large blowing power is used, for one calls for large coolant passages with moderate gas velocities, the other for small coolant passages and high gas velocities. In order to express the influence of these variables on the design as a whole it is again necessary to carry out numerous calculations.

The number of variables is so great that no straightforward calculation will give directly the best system to adopt, and other factors must also be considered, such as the desirable diameter of pressure vessel and any restrictions fan characteristics may impose on the system. Consequently in selecting a design, judgment plays an important part.

THEORETICAL AND PRACTICAL SIZE

In the final choice of parameters for the reactor system, it should be remembered that whereas it is possible to define a critical size for any lattice arrangement, it is not sensible to build to this size. There are several reasons for this. In the first place, as has been observed, the fission process in the reactor is sensitive to the temperature of the moderator, so that reactivity is lower at high temperatures; in addition, during operation the reactor will burn up some of its uranium 235 fuel and replace it with fission products, some of which have very high neutron-absorption cross sections. For both these reasons, the pile should be made considerably greater than critical size, with arrangement to absorb the excess neutrons whenever this is necessary.

There are two additional factors which recommend an increase in reactor size. Firstly, in any reactor the neutron flux (and thus heat generation) is by no means uniform throughout the core. If by putting neutron-absorbing material in the central region of the core, or by other means, the neutron flux in the centre can be depressed, or flattened relatively to the outside, the resulting more uniform heat distribution in the core will, together with the restriction imposed on the fuel-element temperature, considerably ease the cooling problem. The degree of this flattening indicates to some extent the success of the compromise between purely engineering and purely nuclear features of the design. For maximum economy of neutrons, an appropriate choice of absorbing material must be made; perhaps thorium or a material useful for isotope production could be employed.

The design of the graphite structure is in itself an interesting problem. The whole assembly contains over a thousand tons of graphite with a few thousand holes through which passes the coolant gas, and in which the fuel elements rest and the control rods, which so far have not been mentioned, must slide freely. The graphite used is of very high purity and density, and each block is fully machined to extremely close tolerances on account of the large number of pieces involved and the danger of cumulative error in assembling the whole structure. Allowance has to be made for thermal expansion and for possible swelling of the graphite during the lifetime of the pile due to damage sustained by its structure from the neutrons which pass through it.

It may be appropriate here to mention that considerable variations in physical properties both of graphite and other materials occur during the operation of a reactor, and it is necessary to make sure that the arrangements are not merely satisfactory initially but will remain so during the lifetime of the reactor. In some cases information on this subject is still very sketchy and much work remains to be done. The design of the graphite structure of this type of pile contributes a great deal to its general soundness and prospects of good behaviour during its life. A large part of the drafting effort will be devoted to this work.

HIGH-DENSITY CONCRETE SHIELD

The reactor as a whole must be surrounded by a shield to absorb the radiation which emerges from it. There is no difficulty whatever in designing a shield which will be completely effective in achieving this. There is, however, need for care in the design since several tens of thousands of tons of concrete are involved. In some ways the design of the biological shield may be regarded as involving a wider range of engineering arts than any other part of the reactor system. The theoretical specification of thicknesses, concrete density, and the size of holes permissible involves a good deal of reactor physics and a knowledge of nuclear reactions, while the structural design is in some cases by no means straightforward.

Although the pile is operating on thermal neutrons, an appreciable number of the neutrons escaping are fast neutrons, and a major function of the biological shield is to slow down or thermalise these fast neutrons in order to promote their capture within the shield. When neutrons are slowed down, and when they are captured, gamma rays are produced, and the limiting factor in the design of the biological shield for a reactor frequently hinges on the absorption of gamma radiation which originates within the shield itself owing to neutron capture. For this reason there is considerable interest, particularly for special applications, in shields either containing boron—which absorbs thermal neutrons without a high-energy gamma emission—or employing high-density concretes, which are particularly good as gamma absorbers.

Both functionally and structurally the shield design is likely to be most difficult at the face where fuel is to be changed, for here the shield is penetrated by a very large number of holes. It is of help if the reactor is shut down during the fuel-changing operation for then there is only the residual activity from the structure members near the reactor to consider; other activities, including that of the fission products in the fuel inside the reactor, are comparatively low. In addition, the actual mechanical design of the change gear is simplified if the gas pressure is lowered during the operation in order to reduce the differential pressure and the difficulty of making sealed joints. However, quite a good case can be made for a scheme in which it is possible to discharge the fuel under full power. The merits of alternative schemes from the design viewpoint must be weighed against the expected operational advantages and disadvantages—loss of operating time in one case, and the need for extremely careful operation planning and control in the other.

In order to protect the concrete shield from radiation damage, a steel or cast-iron inner shield is normally used. This absorbs thermal neutrons and gamma rays leaving the reactor and deals with the major part of the total radiation passing into the shield. In consequence, it is provided with a cooling system, designed mainly for controlling the temperature of the concrete shield; this must be kept within reasonable limits. The importance of the concrete biological shield may perhaps best be illustrated by saying that the neutron flux diminishes to one-tenth of its value at intervals of approximately 6 in., and that the shields used are normally about 7 ft. thick.

COOLING AND CONTROL

The reactor is controlled by the slow insertion or withdrawal of boron loaded rods which can slide into the core for a sufficient distance to quench the reaction by reason of their strong absorption of neutrons. Both calculation and experience confirm that this kind of reactor is inherently stable, and that its control is a straightforward matter. There is some difficulty in calculating exactly the number of control rods required, but there is no difficulty in practice in deciding on a number which will be adequate. The control-gear drives are reasonably conventional, with the motors operated from the control room. Reactor power level is indicated by counting the neutron flux with the aid of ionisation chambers.

The coolant gas is circulated round the pile and the boiler plant by blowers, in which the main design problem is the shaft seal and the fact that they have to operate at rather high pressure. As it is almost a condition of design for the pressure ratio to be low, there is no special difficulty with regard to the aerodynamic design of the blowers. The quantity of gas circulated is quite great and the ducts must be of large diameter in order to keep the pressure drop in the circulation system at a reasonable value. This large diameter gives rise, however, to a fairly serious thermal-expansion problem, which considerably influences the layout of the plant.

A complete plant of this kind is on a rather grand scale. Whereas the diameter of the pressure vessels is likely to be dictated by the maximum thickness of plate which it is desirable to weld on site, the diameter of the heat exchangers was fixed in the case of the Calder Hall piles by the necessity to transport them from the works. They are built from rings about 18 ft. in diameter and have a total height of 70 ft. They embody 30,000 sq. ft. of heating surface distributed between the superheaters, evaporators and economisers of the low-pressure steam system. A low-pressure system is preferred since the temperatures attained in this type of reactor are rather low.

LOW-PRESSURE TURBINES

The steam is taken directly to the generator house where the equipment is of fairly standard design, though because of the low steam pressures

the turbine sets are large for the power they develop. A feature of the combined control system for steam plant and reactor is the use of a separate dump condenser, which allows by-passing of the turbines to give more or less completely independent operation of the reactor, regardless of the requirements of the grid distribution system. This is of value during the commissioning period, for it enables reactor trials to be conducted independently of the turbines. This turbine decoupling effect should make it possible to run the reactor under more nearly uniform conditions than would otherwise be possible. To help this further, a wide range of speed control is fitted to the fans so that reactor operating temperatures may be kept steady, independently of power output, by varying the coolant flow. The remainder of the power-plant side can be quite conventional and has no special problems associated with it.

REPLACEMENT AND STORAGE OF USED FUEL

When the uranium fuel elements have been in the reactor for the necessary period they are extracted, as has been mentioned previously, and they must be stored until the activity has been reduced sufficiently for convenient chemical processing. This is carried out at present by storing them under some 15 to 20 ft. of water, and the ease with which they can be sorted and handled under these conditions is quite remarkable. There is only a slight pick-up of activity in the water during this operation and there seems no reason why it should not become more or less standard practice. Of course, for reactors using fairly concentrated fuels it is necessary to take good care in the design of such a storage pond that the fuel cannot be arranged in such a way that the system of fuel and water moderator may act as a thermal reactor. This is but one particular case of a general difficulty which arises in the handling of highly enriched fuel, either as such or during processing in chemical plants.

The kind of reactor which has been under discussion is seen to be one in which the normal engineering skills in design, development, manufacture and construction require to be reinforced by the comparatively new skill of reactor physics and other specialised skills. It is, however, a type of reactor in which well established engineering skills contribute very greatly to the success of the project.

The author expressed his thanks to Sir Christopher Hinton, Managing Director of the United Kingdom Atomic Energy Authority, Industrial Group, for his permission to present this paper and for his suggestions on its form.

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APPRENTICES IN SMALL FIRMS

Group Scheme in London

In the course of his speech at a London regional luncheon of the Engineering Industries Association on October 5, the chairman, Mr. D. A. Gunn, spoke of the Association's newly-constituted Group Apprenticeship Training Scheme.

This, he said, was intended for the smaller engineering firms having a limited range of manufacturing facilities, and the aim was to pool the resources of a group of companies, thus enabling apprentices to receive a comprehensive training in several branches of engineering. The scheme was administered and the training of the apprentices watched over by a supervising engineer, who relieved individual firms of much of the responsibility involved. The firms in the group nominated the number and grades of apprentice they wished to sponsor and a training programme was prepared for each apprentice. As the young man's training developed, he moved from one firm to another within the group, obtaining in this manner experience on a range of products and under varied conditions. Excellent results were being obtained for the first training group and there was every prospect that the scheme would grow.

The Institution of Naval Architects Autumn Meeting (continued from page 484)

SHIP PERFORMANCE AND BEHAVIOUR

FUEL CONSUMPTION ANALYSED: A BASIC THEORY OF PITCHING AND HEAVING

After the formal opening, on the morning of Monday, September 19, of the Institution of Naval Architects' Autumn Meeting in Yugoslavia, the members of the party were free during the afternoon to explore the attractive town of Opatija, which was their headquarters for four days; but in the early evening the introductory social functions were inaugurated with a reception by the Lord Mayor of Rijeka in the Town Hall of that city, an imposing building constructed in the late 'nineties and formerly the residence of the Austrian Governor of the Province. The Lord Mayor, Mr. Edo Gardas, who had lived for a number of years in Canada, welcomed the Institution in excellent English, and invited their attention to the Art Gallery and the small Maritime Museum which are housed in the building. In the Museum they were interested to find a builders' scale model of the steamer Partizanka, the vessel which had been chartered for the 2½ days cruise down the Dalmatian coast that was to follow the technical sessions.

Later in the evening the members and their ladies were the guests of the Yugoslav Society of Naval Architects at a performance, in the People's Theatre, of the opera, "Ero from the Other World," by the Yugoslav composer J. Gotovac.

TECHNICAL SESSIONS

On the following morning, September 20, in the Hotel Parme at Opatija, the first of the four technical sessions was held, the chair being taken by Mr. R. B. Shepheard, C.B.E., B.Sc., the chairman of the Institution Council. In the course of these sessions, six papers were presented and discussed, these being: "Measurements on the M.V. 'Rijeka,' with their Attempted Practical Application," by Professor Ing. S. Silovic and Ing. M. Fancev; "The Pitching and Heaving of Ships," by Mr. A. J. Sims, O.B.E., and Mr. A. J. Williams; "Frictional Drag of Smooth and Rough Ship Forms," by Ir. A. J. W. Lap; "Organisational Developments of the Uljanik Shipyard" by Ing. Djuro Stipetic; "The Recent Development of the Shipyard at Split," by Mr. M. Stanger and Mr. S. Ercegovic; and, finally, "The Design of Economic Tramp Ships," by Dr. E. C. B. Corlett.

FUEL MEASUREMENTS ON M.V. RIJEKA

The paper which Professor Silovic and Ing. Fancev presented on behalf of the Shipbuilding Research Institute (Brodarski Institut) at Zagreb summarised the results of a prolonged series of observations, extending from January 21 to May 14, 1954, on a voyage from Rijeka to Oran and thence to Tangier, Hamburg, Bremen, Rotterdam, London, and back to the Adriatic. The Rijeka is a shelterdeck vessel of 2,337 tons gross and a deadweight capacity of rather more than 3,900 tons. Her principal dimensions are: length overall, 352 ft. 7 in. and between perpendiculars, 326 ft. 5½ in.; breadth moulded, 46 ft. 7 in.; depth to upper deck, 28 ft. 3 in.; and summer loaded draught, 18 ft. 2 in. The propelling machinery, a Burmeister and Wain six-cylinder single-acting two-stroke oil engine of 3,100 h.p., gave her a maximum speed, during the voyage indicated, of 13½ knots. From the records taken, a daily fuel consumption diagram (D.F.C. diagram) was prepared, relating the fuel consumption, the ship's speed, the propeller revolutions, and the torque in the propeller shaft (measured by a Maihak torsionmeter), from which the fuel consumption to be expected in given circumstances could be estimated. Comparison of the results indicated by this diagram with actual fuel consumptions of the three sister ships Rijeka, Pula and Zadar, obtained from the engineers' voyage reports, showed satisfactory agreement. The influence of weather conditions on the speed and the revolutions was also discussed in the paper, and an economic analysis of the ship's performance in service was given for various speeds, weather conditions and deadweights. The authors admitted that it had been "necessary to 'treat' the results obtained from the measurements with much practical experience in order to obtain a form that will correspond to the propulsion laws of a ship," but they expressed the hope that they had done enough to demonstrate to shipowners the benefits of adequate instrumentation and systematic recording of the information that the instruments afforded.

MERITS OF D.F.C. DIAGRAMS

Dr. R. W. L. Gawn, C.B.E., who opened the discussion, said that the authors had presented their performance data in an instructive and refreshingly clear manner, and their daily fuel consumption diagram seemed to have considerable merit as a basis. Apparently, the recorded consumption was about 2 per cent. greater than the calculated figure for passages from the Adriatic to North Sea ports, but on Far East voyages the margin was increased to about 8 per cent. Reduced engine efficiency due to higher temperatures, and perhaps less favourable sea conditions, might contribute to the greater fuel consumption on the eastern route, but he suspected that hull fouling was also a factor. The assumed average daily increment of skin friction of one-eighth per cent. was probably reasonable in temperate seas, but the rate might well be doubled in tropical waters. Skin friction resistance would also vary with the procedure in hull coating and might be greater if the hull were merely "touched up" on docking, instead of being completely scraped and painted. The frictional torque of 75 kgm. quoted was equivalent to only about ½ per cent. of the maximum engine torque recorded, though about 2 per cent. of the minimum. Shaft friction was liable to vary with the tightness of the stuffing-box gland, and would affect the fuel consumption. The frictional torque appeared to have been determined from a dock test; if that was so, the authors' figure seemed really to be the "frictional remainder" and a larger allowance would be appropriate to operational performance. It might be possible to elucidate that from measured-mile trial results in calm water.

He invited the authors' opinion of the general reliability and accuracy of the Maihak torsiometer, which appeared to him as being a handy and convenient instrument. Comments on the overall accuracy and operation of the speed log would also be welcome. He expressed appreciation of the careful recording and detailed analysis of the comprehensive information included in the paper, which contained much of interest to shipowners, shipbuilders and naval architects. He hoped, however, that the authors would see their way to include trial results in the paper, together with those of the relevant model tests.

COMPARISONS WITH MODEL TESTS

Dr. Ir. W. P. A. van Lammeren said that results such as the authors had given were scarce. The Netherlands Ship Model Basin was highly interested in them, because a model of the Rijeka had been tested in their establishment. The results given in Table I of the paper were plain and uncorrected, but the authors apparently concluded that a number of them must be wrong. The deviations could be explained, however, by the resistance log when it was towed.

Though he appreciated the open and uncomplicated treatment of the results, he thought than an even stricter selection of the measured results was possible. Assuming that the measurements of r.p.m. were reliable, wrong speed measurements could be detected by plotting r.p.m. on the basis of speed; that could be done for different displacements by correcting the r.p.m. by a percentage equal to one quarter of the percentage difference in s.h.p., which might be taken to vary as the two-thirds power of the displacement. Fairly consistent results were obtained in that way, except for the voyage from Oran to Tangier under very bad weather conditions, and the voyage from Rijeka to Dubrovnik, when the displacement was so small that so simple a method of correction was no longer valid.

The results with reliable speed measurements might be divided into three groups, namely: (*a*) those made in fine weather, corrected to a standard displacement of 6,232 tons, for which model experiments were carried out; (*b*) fine-weather records for the smallest displacement, uncorrected; and (*c*) those measured during bad weather. Unfortunately, no self-propulsion tests were carried out with a model of the Rijeka fitted with a model of the actual screw; therefore, the results of the self-propulsion tests could not be compared directly with those of the ship. However, from tests with a different propeller of the same r.p.m. and approximately the same diameter, the effective wake fraction as well as the thrust-deduction fraction and the relative rotative efficiency were known. By applying those values to the propeller of the Rijeka it was possible to make a prediction for the ship in her actual condition. In his opinion, the agreement for fine-weather conditions was very satisfactory, especially in view of the fact that the measurements were taken from 10 to 12 months after docking.

If the examination of the authors' results were restricted to values found under favourable weather conditions and with the bigger displacements only, the picture might become different to some extent. He had also calculated the relation between $\frac{Q}{N^2}$ and $\frac{V}{N}$ for the screw under consideration from the open-water diagram for several values of ψ. It was found that $\psi = 0{\cdot}25$ was in good agreement with the ship data, and with the value of $0{\cdot}26$ which was found for the model. Scale effect in frictional wake could account for the small difference. However, there was also an appreciable difference in slope between $\frac{Q}{N^2} - \frac{V}{N}$ curves derived in that way and the curves given by the authors. It would be interesting to investigate how far that different slope might affect the rather surprising result mentioned, namely, that the Diesel engine would have delivered a constant output with the fuel control lever in a constant position and under changing weather conditions.

ACCURACY OF SPEED MEASUREMENTS

Dr. Ing. K. A. G. Kempf said that the particular aim and value of this paper, to afford the shipowner a reliable basis for the daily fuel consumption of his ship under average service conditions, was certainly achieved by the reported measurements; they showed what the model tank could do for the shipowner. The difference between the calculated average and the reported daily fuel consumption invited investigation. More than usually adverse weather, or deterioration of the hull surface, or something wrong with the propeller or with the engine, might account for it. Especially interesting was the influence of weather conditions. All measurements on ships should be carried out by the same methods, under continuous supervision of the measuring devices and by a trained staff. Only under such conditions was it possible to obtain such valuable information as the authors had given in their paper.

Mr. A. R. Mitchell, M.B.E., thought that the only weak link in the Author's results lay in the admitted inaccuracy of some of the speed figures recorded by the resistance log. It was stated that that method revealed immediately those errors of measurement which did not result from the standard inaccuracy of the instruments, but from other causes. When compiling trial data, engineers were always most insistent on the accuracy of their figures of power obtained with a torsionmeter, the revolutions shown by the counters, and the fuel consumption figures. Naval architects replied by measuring times on the measured mile to fifths of a second. Under service conditions, however, that was not possible and they had to depend on the log, which gave a good approximation to the speed, but was subject to tide effects. Did the authors, he asked, check the speed on the known distance between certain ports? The paper was probably of greater interest to the shipowner than to the shipbuilder, for it enabled the shipmaster to ascertain what the fuel consumption would be if the displacement of the vessel and the weather intensity were known; but it was also of great interest to the designer, for such data were most difficult to obtain.

The summary of the paper referred to "an instrument for control of fuel consumption." Did that refer to a mechanical instrument, and, if so, was it pre-set to take account of displacement and weather intensity; or did the word "instrument," merely indicate the method of obtaining that information by the use of the charts? The figure of 62 per cent. given for the time spent in harbour appeared to be high, for Dr. Corlett, in his paper on the design of economic tramps, gave a figure equivalent to 55 per cent. A Scottish shipowner friend also, had given him a figure of 58 per cent., so that the 62 per cent. seemed not unreasonable.

ENGINE BEHAVIOUR

Ir. A. J. W. Lap, following on Dr. van Lammeren's reference to the somewhat peculiar result of the Diesel engine delivering a constant output instead of a constant torque with the fuel control lever in a constant position, said that he would expect the torque to remain constant when the same quantity of fuel is injected per revolution. He had plotted the torque values given on a base of the position of the fuel control lever, and found that the delivered torque corresponding to a certain position of the fuel control lever decreased with time. For that phenomenon, several explanations were possible. There might have been some change in the mechanism of the fuel control, though the plotted results gave the impression that the change occurred more or less gradually, and after the fourth day a stable condition seemed to have been attained. A second possibility—of academic value—was that the efficiency of the engine was decreasing or that the calorific value of the fuel was decreasing with time. A third possible cause was a change in the zero calibration of the torsion meter. At the Wagenigen tank, they had had much experience with the Maihak torsion meter and they knew that a wandering of the zero calibration was possible unless effective measures were taken to prevent stresses in the apparatus. Therefore, he asked whether the authors had an opportunity to calibrate the torsion meter during their trip in the Rijeka, and, if so, whether the results threw any light on the phenomenon mentioned.

Dr. E. C. B. Corlett drew attention to the authors' conclusion that ships in the service described would never reach their economical speed at all, even under ideal weather conditions. Mr. Mitchell had commented on another feature, namely, the time spent in port. Dr. Corlett asked whether the authors would agree to reduce the figure of 62 per cent., as the amount of time spent in port, to 55 per cent., and to estimate the effect on the economical speed of the ships; because, if it were possible to turn the ships round more quickly, that was a much more economical way of recovering their cost. A ship was only earning money when she was at sea. He suggested to the authors that, taking the ships at their present designed service speed, they should estimate the percentage of time spent in port that would enable them to retain their economic speed.

Mr. J. D. Calder, who said that he had made voyages in the ships mentioned in the paper, noted that the Rijeka was docked on March 13, 1953, and April 24, 1954. Was that the usual interval between dockings? He had had considerable experience with ships in the eastern Mediterranean, and had found it better to dock them at intervals of six months. He did not agree with Dr. Corlett's assertion that ships did not earn money in port; after all, the purpose of the ship was to carry cargoe, and how could she carry cargo without loading and discharging it?

Mr. D. Gospodnetic, a scientific officer of the Brodarski Institut who had carried out the observations in the Rijeka referring to the Maihak torsionmeter and other instruments used in the work said that the Maihak instrument had the advantage of being purely mechanical; electrical instruments might be more sensitive, but they were not so accurate. The pick-up of a torsionmeter might stick momentarily, and the recording instrument did not arrange the torque per revolution, but in most cases, that was not important. There was no entirely satisfactory instrument for measuring speed The Kempf log might be improved by eliminating the effect of the towing wire.

Professor Silovic, replying to the discussion, thanked the various speakers for their remarks and said that he would reply to their questions in writing.

PITCHING AND HEAVING OF SHIPS

The second paper in the programme, on "The Pitching and Heaving of Ships," by Mr. A. J. Sims and Mr. A. J. Williams, was presented in summary by Mr. Williams, who explained that it was the result of a re-examination of the theory of the subject with a view to a clearer understanding of model experiment results and seagoing behaviour. Basic theory showed that both pitching and heaving were special cases of the classical theory of oscillations; though, when experimental results were plotted in accordance with the conventional method, the correspondence with oscillation theory was not obvious. In the rolling of ships, the amplitude of the forced roll could be related directly to the maximum wave slope, but in pitching the results were complicated if the amplitude was related to the maximum wave slope, because the contour of the wave could only rarely be taken as a straight line on the ship's profile. If a wave were imagined to be slowed down with relation to the ship, so that she could balance statically on the wave at every moment of its passage, the ship would pitch in the effective period of the wave and a static amplitude would result. If the wave were speeded up to its correct velocity, a dynamic amplitude would be produced. The static amplitude would be less than the wave slope. Similarly, the results for heaving were obscured if the amplitude were related to the wave height; on a slowed-down wave, the ship would lift or drop slowly in the effective period of the wave so as to equate weight and buoyancy at each position of the wave. The vertical motion would be less than the wave height.

The oscillations of a body floating in still water, Mr. Williams continued, were accompanied by a complex disturbance in the water, which had the two effects of damping the amplitude of the oscillations, and prolonging the period of oscillations beyond what would be expected from hydrostatic considerations. The theory indicated that an increase in period would result from the damping effect, but the actual increase was only partly attributable to that cause; the major increase resulted from the fact that the oscillating system consisted of the body and the medium, in combination. The paper described the method that the authors had evolved for plotting experimental model data in a form compatible with the theory of oscillations and suitable for a more critical

examination of the data obtained, and discussed the application of the method to model data for an aircraft carrier and a frigate, supplied by the Admiralty Experiment Works at Haslar.

EFFECT OF VESSEL ON WAVE SYSTEM

The discussion was opened by Professor Sir Thomas Havelock, F.R.S., who said that he found the paper refreshing; the authors had developed a fresh idea and had succeeded in giving a new look to the familiar theory of heaving and pitching. That theory was, of course, inadequate to deal with the problem completely and it was in need of modification and extension in many ways; at times, it had been criticised unduly, but, as the authors had pointed out, that was partly due to the manner in which the results were presented. The paper was, therefore, opportune and welcome. Its kernel, in his opinion, was equation (x), the equation of the magnification factor μ, which was shown to be independent of form and wave length. He would like to see some attempt made to take account of the disturbance of the wave-pressure system caused by the ship, including, if possible, the effect of speed of advance. There was also the important question of the coupling of heaving and pitching. These, however, were matters for future development; the best line of attack might well be indicated more clearly by further experience with the new method of presenting the results of the approximate theory. He congratulated the authors on a valuable and successful piece of work.

Dr. R. W. L. Gawn, C.B.E., said that firmer understanding of pitch and heave oscillations was essential if the growing emphasis on improved steadiness and sustained speed at sea was to be fruitful of results. He welcomed the paper accordingly. The conception of rolling had long been substantially clear, and much of the experience with ships at sea could be explained by the simple linear theory, largely because the waves of real interest were long in relation to the beam of the ship. There had been elegant mathematical solutions of pitch and heave, but factual application to ships had been limited by a number of complicated factors. One stumbling block was that the length of ocean waves which promoted objectionable motion was more or less commensurate with the length of the ship. The authors had surmounted the difficulty admirably by developing an analytical theory based on the static amplitude. Their Fig. 7 (a comparison of actual and derived results for an aircraft carrier model) showed remarkably satisfactory agreement between calculation and experiment, on the whole. Detailed examination indicated that the two sets of curves were practically indistinguishable at the extremes of large and small amplitude, but the calculated motion was greater in the middle zone by about 10 to 15 per cent. or more, depending on speed and tuning factor. It would be instructive if the authors could give the modification necessary to the damping and inertia coefficients for closer agreement in that region. Strictly, of course, the coefficients were probably not discrete, as assumed, but depended on the speed, the period of encounter and the amplitude of motion, among other factors. Detailed exploration should prove rewarding, as the zone concerned was that of greatest operational interest and represented the conditions most frequently experienced at sea. The results would throw light on the increase of damping required to effect a worth-while degree of stabilisation in that zone—say, a reduction of 20 per cent. or more of amplitude. A fairly substantial change in hull form, with perhaps a modification of radius of gyration, would probably be involved.

SIGNIFICANCE OF REDUCED STERN MOVEMENTS

Fig. 12, illustrating vertical movement along the length of a ship, indicated that the motion at the stern was much less than at the bow, which was important operationally for aircraft carriers, since the range of sea conditions under which an aircraft could land on the flight deck was thereby increased. The characteristic arose from the phase difference of pitch and heave, and special attention was now given to it in model experiments, the movement both of bow and of stern being measured directly, as well as the pitch and heave generally and the phase of the oscillations. The results of some model tests afforded a degree of support for the claim by the authors that the phase difference might be 90 deg., under certain conditions, and thus conducive to minimum stern motion. Sir Thomas Havelock, in a recent paper, had shown that to be theoretically true for a mathematical shape in still water. However, model tests at Haslar had also indicated departures from 90 deg. phase up to about 30 deg. or more, depending on the speed of the ship and the length of the wave. That reacted on the limitation of stern motion and, accordingly, there was scope for further investigation of phase difference, both by theory and experiment.

The dominance of length of wave in determining the amplitude of pitch and heave had been well confirmed by model tests and was supported by the present paper. It was for that reason that results obtained at Haslar were related to the wave factor. He hoped that the authors would endorse that practice. The complete presentation proposed in the paper he considered to be important, but for selected application; any attempt to follow it generally would involve considerable effort and would unduly expand investigations on seaworthiness, which already entailed a very lengthy effort in analysis, particularly with additional measurements such as acceleration and slamming. It was also the practice at Haslar to relate results to the tuning factor; but the virtual mass was neglected, being largely unknown. Even for a given ship, it appeared to be variable and to depend on the speed and the state of the sea.

Dr. Ing. W. P. A. van Lammaren observed that the references given in the paper (to Professor Havelock's paper of 1945 and Mr. J. L. Kent's of 1934) did not go far back; no doubt, the authors would know that some valuable contributions had been made recently by other scientists, such as Weinblum, St. Denis, and others. He asked whether they had taken the results of that other work into account, and, if so, whether the results were in agreement with their own work.

Dr. W. Muckle, remarking that he approached the problem from an academic point of view, that of one who had to expound the theory of pitching and heaving to students, said that the authors had given an excellent extension of the simpler theories, and had made clear the marked difference between the rolling problem and the pitching and heaving problem. Of course, the theory of rolling assumed that the breadth of the ship was small in relation to the length of the waves. Were the slope and height of the subsurface wave used in the theory? Coupling had been mentioned by Sir Thomas Havelock, and he would like the authors to expand their theory to include that effect. Did they think the influence of coupling would be serious? Would it influence greatly the results they had obtained already? He was particularly interested in virtual mass and damping equations. In connection with virtual mass in this complicated movement of the ship, neither pitching nor heaving could exist without the other coming into it. He thought that there must be two different virtual masses, one for heaving, where there is a vertical bodily up-and-down motion, and another for pitching, where there must be some three-dimensional flow of the water along the hull of the ship.

Perhaps the authors' work would make possible a further advance in determining the influence of pitching and heaving on longitudinal stress. That matter was not dealt with directly in the paper; but since there was close agreement between forecasts by the authors' theory and what was likely to be obtained from model experiments, perhaps they might go on to calculate what would be the additional bending moment, etc., put on to the ship as a result of pitching and heaving.

EXTENSION OF THE ANALYSIS

Mr. Sims, replying to the discussion, said that he and Mr. Williams had tried to do no more than to put the basic approach correctly from the naval architect's point of view. They had tried to give a fundamental theory which was correct, hoping that other workers in that field would see how it worked out in practice and perhaps, in due course, would elaborate it still further. Sir Thomas Havelock had referred to improvements which might be made. They were, of course, conscious of the fact that the full hydrodynamics of the system round the ship were not quite as they had assumed in the paper; for example, that the behaviour of a ship in a wave system did not alter to the pressure system indicated by the simple wave theory. They would have liked to take account of the modification of the wave system by the presence of the ship and to modify the theory to that extent. It would be helpful if anyone could find a way to determine that modification.

Some speakers had spoken of the coupling of the pitching and heaving systems. It had to be assumed that the two actions could be considered separately and then superposed. The results so far achieved encouraged the belief that such an approach was reasonable. It was not claimed that the phase difference was exactly 90 deg.; it might be a little more or a little less, and it would be interesting to find by experiment what the actual difference was at different speeds.

Dr. Gawn has mentioned the divergence in the middle of Fig. 7. That difference might be due to a variation of the damping factor, a variation of the virtual mass, the introduction of damping varying as some other power of the velocity, or simply to the fairing of the points obtained experimentally. The method outlined should enable those factors to be more clearly appraised in future experiments. Regarding Dr. Gawn's reference to the changes required to achieve improved damping: Fig. 8 in the paper gave the results obtained with shallow waves and with deeper waves, and afforded some opportunity of assessing what variations in a ship's form away from the waterline would do. The lower curves illustrated the extra damping provided by such factors as flare forward, stern shape, etc., when the ship was pitching heavily.

Dr. van Lammeren referred to the small bibliography at the end of the paper. It was not intended to be comprehensive, and mentioned merely the papers on which the authors had actually drawn in developing their particular approach; there were other workers who had made very fine contributions in that field. Dr. Muckle suggested that the effect on longitudinal stresses could be investigated by the method outlined. There were increased possibilities in that direction, although it was not considered that such calculations should be done as a matter of routine.

(To be continued)

* * *

FOUNDRY DEVELOPMENTS

Düsseldorf Congress and Fair

For the first time, an International Foundry Trades' Fair will be held at Düsseldorf and will occupy the whole of the city's exhibition halls and grounds, including some 450,000 sq. ft. of indoor floor space, from September 1 to September 9, 1956. The fair, which is to be known briefly as the GIFA (Giesserei-Fachmesse), will be the first foundry trades' exhibition to take place in Germany since 1936 and will be held in connection with the 23rd International Foundry Congress, which is also due to take place at Düsseldorf. It is being organised by the Nordwest-deutsche Ausstellungs-Gesellschaft m.b.H. (NOWEA), Ehrenhof 4, Düsseldorf, whose London agents are John E. Buck and Company, 47 Brewer-street, Piccadilly, W.1.

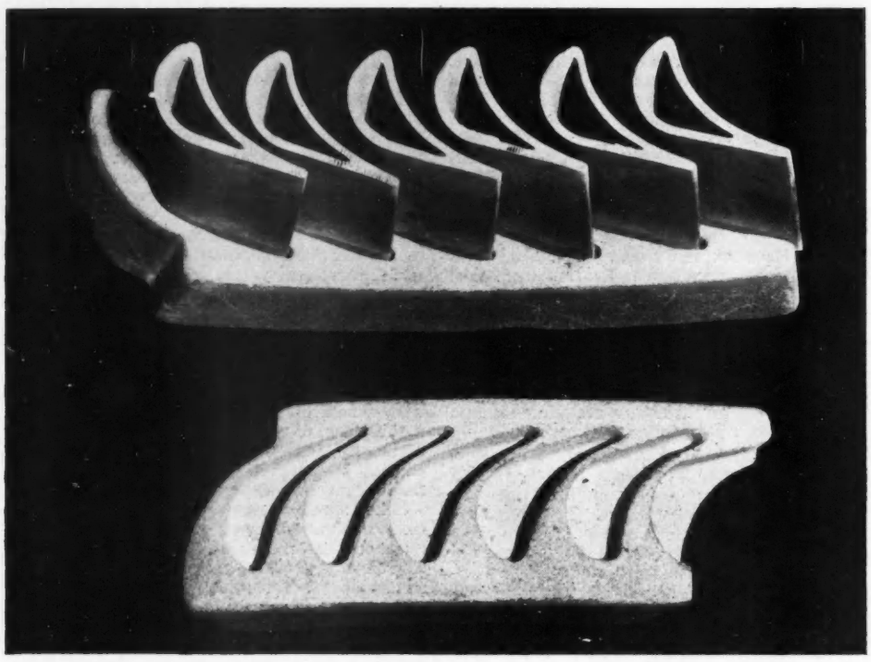

Fig. 1 Detail of ceramic stator blading, shown in Fig. 2. The rotor, which is subjected to high centrifugal loading, has hollow metal-alloy blades cooled by liquid-metal convection.

TURBINE DEVELOPMENT

OPEN HOUSE AT PAMETRADA

Since publication of their 1954 report (see ENGINEERING, July 22, page 101, 1955), the Parsons and Marine Engineering Turbine Research and Development Association (Pametrada) have continued their work on high-temperature gas and steam turbines, and have also undertaken several additional investigations; they have, for example, begun trials on a double-casing high-pressure steam turbine and developed a method of balancing rotors *in situ* aboard ship. The occasion of their open week, which began on Monday, October 3, offers a suitable opportunity to review progress made so far during the current year. Other problems tackled within this period include: fouling and corrosion; the handling of liquid metals for turbine-blade cooling; refractory flame tubes and turbine blades; water lubrication; and steam sampling. The association has also developed a hydraulic transmission for gas and steam turbines employing an oil-operated reversing mechanism—one of them is to be fitted in the tanker Auris (ENGINEERING, September 9, page 324, 1955)—and completed comparative studies of various propulsion systems, including one powered by a nuclear reactor.

As an introduction to the work of the association, and to indicate its scope, reference can usefully be made to the achievements of the design section, which in just over ten years has supplied basic turbine information in response to 713 inquiries and has contributed to the final design of machinery for 240 vessels. The total s.h.p. of engines completed to Pametrada design and already in service is approximately 2,314,000. During this period, turbine weights have been reduced by some 30 per cent. and gearing weights by 50 per cent. Average fuel rates have improved by 15 per cent. and costs of manufacture based on current prices reduced by 15 per cent. These changes have been accompanied by an improvement in reliability.

HIGH-TEMPERATURE GAS TURBINE

One of the most interesting current studies at the Pametrada laboratories concerns the development of a high-temperature gas turbine and the use of liquid metals for blade cooling. By increasing the maximum cycle temperature of a turbine a considerable increase in overall thermal efficiency can be obtained since a lower air mass flow is possible than in a conventional gas turbine for the same power and outlet temperature; thus the heat loss in the exhaust is very much reduced. This is a simple case of increasing the Carnot cycle efficiency by increasing the working temperature of the fluid.

The advantages of the high-temperature cycle are indicated in the table below, which gives figures for turbines with heat exchangers of 75 per cent. thermal ratio, having intercooling, and operating at the optimum pressure ratio for each temperature. The reduction in air rate permits a considerable reduction in machinery size; for example, the volume occupied by a 1,250 deg. F. turbine plant is approximately 31,200 cub. ft. and by a 2,200 deg. F. unit 16,800 cub. ft. The engine-room space required is thus almost halved. In this comparison the machinery considered is for a 10,000 s.h.p. engine with reheat in the case of the low-temperature turbine. Gearing for the two turbines differs little in size and is included in the stated volumes.

Cycle temperature	1,250 deg. F.	2,200 deg. F.
Overall thermal efficiency (including cooling losses) ..	28·8 per cent.	38·8 per cent.
Air rate (lb. per b.h.p. hr.) ..	62·0	16·5

The efficiency of 38·8 per cent. for the high-temperature gas turbine is about 1·35 times that of a marine steam turbine, which lies between 28 and 29 per cent., where the inlet conditions are 650 lb. per square inch and 850 deg. F. Distillate fuel costs about 1·5 times the price of residual fuel, and the advantage of the high-temperature gas turbine can therefore only be maintained if it is designed to run on residual fuel.

Increasing the maximum cycle temperature entails cooling those parts of the turbine exposed to the gas stream; these components are: the rotor blades, the stator blades, and the turbine annulus walls and ducts. The last two items can be made from ceramic and Fig. 2 shows the casing, with ceramic nozzle blades in position, of the Pametrada single-stage high-temperature gas turbine now under test; a group of blades can be seen in greater detail in Fig. 1.

CONVECTION COOLING BY LIQUID METALS

The rotor blades, however, are subjected to high centrifugal stresses and must be made from materials of considerable strength. At present only metal alloys fulfil this qualification and temperatures must therefore not exceed about 1,200 deg. F.; it follows that some form of cooling must be employed. The most suitable method of cooling rotor blades for marine application is by means of a liquid metal sealed inside the hollow blade. The heat is transferred from the hot aerofoil surface to the upper root section of the blade, which in turn is water cooled. The temperatures involved are as follow: hot gases meet the blades at 2,200 deg. F.; the blade surface is cooled to 1,200 deg. F. by liquid metal, which carries the heat to the blade root; finally the blade root at 200 deg. F. is cooled by water at 80 deg. F.

Cooling of the exposed blade is effected by natural convection; under static conditions, with gravity the only force acting on the liquid, the convection currents would be too small to achieve the result required, but with the large forces arising from high rotational speeds the circulation of the liquid is rapid. The eutectic alloy of sodium and potassium is used and, although its heat-transfer properties are not so good as pure sodium, it has the advantage of being liquid at normal temperatures.

Experimental work on blade cooling by natural convection is being carried out at Pametrada by means of an electrically heated blade carried on a rotating arm. The efficiency of this form of rotor cooling is high since it does not interfere with the flow of gas past the blade; the only loss is the heat which is transferred to the water passing over the blade root. The graph in Fig. 3 shows the effect of rotor speed on blade temperature, and a comparison of various liquids as blade fillings is given in Fig. 4. The cooling of stator blades and duct surfaces is also under investigation together with the problems of fouling and corrosion; the high temperatures involved have also led to the development of refractory flame tubes. Fig. 5 illustrates the construction of a flame tube used in the high-tem-

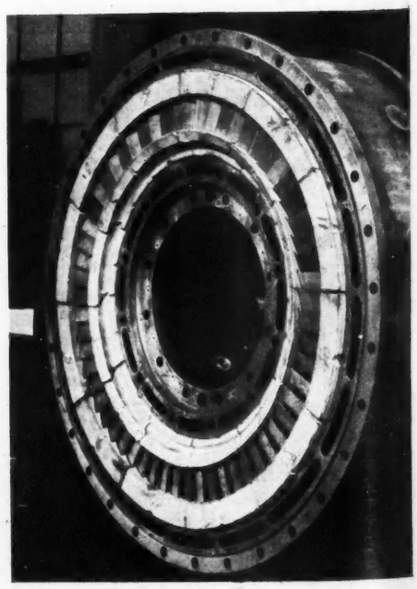

Fig. 2 Casing and ceramic nozzle blades for high-temperature liquid-cooled gas turbine now under test at the Pametrada Research Station. Cycle temperatures of 2,200 deg. F. are envisaged.

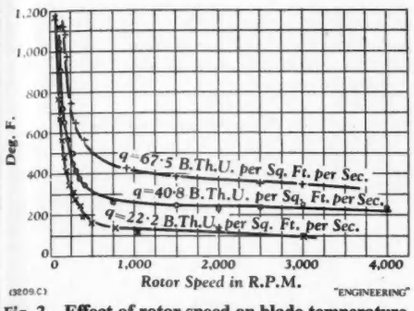

Fig. 3 Effect of rotor speed on blade temperature. Curves of temperature difference between heated and cooled parts of a test blade versus rotor speed, for a given constant heat input.

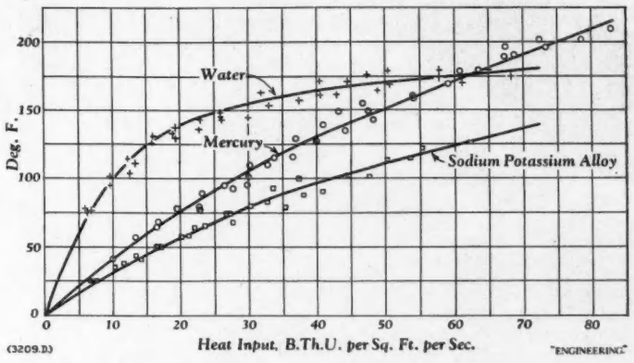

Fig. 4 Comparison of liquids as heat-transfer agents inside a sealed hollow turbine blade. Temperature difference between hot and cooled parts of blade versus heat input, for constant rotor speed.

perature turbine; as can be seen the method of securing the refractory material allows for expansion.

DRYBOX FOR HANDLING LIQUID METALS

To fill the hollow blades with sodium or sodium-potassium eutectic, special techniques are necessary. Sodium, potassium and sodium-potassium alloys react violently with moisture and generally ignite spontaneously in air at elevated temperatures. Furthermore, their rate of oxidation in the presence of atmospheric air is extremely high and the oxide not only causes increased attack on metal containers, but also raises the viscosity to such an extent that blockages frequently occur. It is therefore essential to surround these metals with an inert atmosphere such as pure nitrogen, argon or helium while they are being handled both for safety and to prevent oxidation.

To overcome this difficulty, use is made of the "drybox" shown in Fig. 6, which was introduced at Pametrada on the basis of experience gained from the Atomic Energy Research Establishment at Harwell, where the problem of handling liquid metals had already arisen. The apparatus consists of a stainless-steel container, in which the work is performed, and through which helium is continuously circulated. Access is provided by rubber gauntlets conveniently placed adjacent to armourplate glass windows, and several sizes of posting boxes incorporating air locks are fitted to allow tools, workpieces and other items to be introduced or withdrawn. A neoprene balloon, or gas holder, maintains the chamber at a comfortable working positive pressure of 1·5 to 2 inches water gauge.

The helium is continuously pumped through a dryer and purifier and via the gas holder to the drybox in a closed circuit so that the accumulation of any moisture or other contamination is avoided. A heavily damped aperiodic balance fitted with a graticule scale is situated inside the box for weighing out the required quantity of alloy. This is metered directly into the blade through a porous glass filter. The blade is then sealed with a plug welded in place by means of a special welding unit. Incidentally, the helium atmosphere within the box simplifies the process of welding.

HYDRAULIC REVERSING TRANSMISSION

With the development of the gas turbine for marine propulsion the need arises for a simple and efficient method of reversing vessels so driven. These conditions are satisfied by a hydraulic reversing transmission combined with a hydraulically operated friction clutch for continuous ahead running; a system of this kind is, in addition, comparatively inexpensive. In the case of a steam turbine fitted with hydraulic transmission, no astern turbine is required and the associated problem of thermal distortion at the high temperatures now used is eliminated.

The transmission unit comprises on the primary train an ahead fluid coupling or fluid flywheel associated with a hydraulically operated friction clutch, and an astern converter or coupling. The arrangement is illustrated in Fig. 7. In confined waters or when manoeuvring the friction clutch is not in operation, and ahead or astern drive is obtained by filling either the ahead or the astern coupling.

The turbine is connected in the usual manner to a quill shaft which passes through the bore of the primary pinion. At the forward end of this pinion is attached the driven half of the astern coupling, and at the after end is the driven half of the ahead coupling. The driving halves of both couplings are rigidly connected to the quill shaft. The couplings have drain holes at the outer periphery to allow for continuous forced drainage under the action of centrifugal force, so that a continuous supply of oil has to be maintained to either coupling to keep it running full. Emptying can be completed in a matter of seconds for both couplings. The astern coupling differs in principle from the ahead only in that a row of fixed blading is interposed between the two halves, which reverses the peripheral flow direction of oil issuing from the driving half of the coupling, and thereby reverses the direction of the driven member. The torque on the fixed blades is equal to the difference between the input and output torques and the fluid is deflected through about 140 deg.

For ahead operation, therefore, under manoeuvring conditions, the ahead coupling is maintained full of oil and transmits the power at about 96 per cent. efficiency. On receipt of an order for astern rotation the oil supply is switched from the ahead coupling to the astern. The ahead coupling thereupon empties and the astern coupling becomes full and transmits the drive power in the reverse direction. Reversal of this operation empties the astern coupling, fills the ahead coupling and provides ahead rotation once more.

FRICTION CLUTCH FOR STEADY AHEAD

For steady ahead conditions the friction clutch is brought into operation. Basically this comprises a clutch plate in splined attachment to the quill shaft and free to move axially under the influence of hydraulic pressure and against the resistance of springs. This clutch plate engages with an extension of the ahead driven half of coupling and therefore transmits the drive without slip to the pinion shaft when hydraulic pressure is applied. This pressure is self-generated by the rotation, and therefore, to bring the friction clutch into operation, the ahead oil supply is switched from the ahead coupling to the chamber between the forward face of the clutch plate and the aft face of the outer casing of the ahead coupling. The pressure generated brings the friction faces into contact. To disengage the friction clutch the oil supply is switched from this chamber to the ahead coupling, the chamber empties via the drain holes, and the clutch plate disengages under the influence of the springs.

One oil valve controls all manoeuvring, supplying oil either to the astern converter, the ahead coupling or the direct-drive clutch as required, with a simple interlock to prevent mishandling of the turbine throttle during the operation. Devices for limiting the torques and thrusts developed during manoeuvring are incorporated, although not shown in detail on the drawing. The drive for the auxiliary generator is taken from the aft end of the quill by means of a simple hydraulic coupling. By this means electric power may be generated either at sea with the main shaft rotating, or in harbour with the propeller stopped.

The separate items may now be considered in greater detail. The ahead coupling consists of two identical rotating members having radial vanes. The driving wheel, whch is connected to the prime mover, acts as a centrifugal pump taking in fluid at its inner radius and discharging it at the outer radius with a large whirl velocity. This fluid then enters the driven turbine wheel, which is rotating at a speed 1·5 to 3 per cent. lower than the pump wheel, so producing a torque due to the change in whirl velocity. Since the input and output torques correspond to this arrangement the efficiency is equal to (1 minus the slip), that is, the normal efficiency lies between 97 per cent. and 98·5 per cent. The power lost is required to circulate the fluid round the circuit against friction and shock loss, and the heat generated is carried away by the fluid. Oil drain holes are provided at the periphery from where the oil flows to a small cooler before being again introduced into the coupling. The casings of the coupling are fixed to the driving shaft, thus almost eliminating disc friction between the wheels and the casing.

Since the power input to the coupling is proportional to the cube of the rotational speed and the power absorbed by the propeller is proportional to the same quantity the coupling will operate at the same slip, and hence the same efficiency, at all powers. Some idea of the size of an ahead coupling may be obtained from a design of coupling for 7,500 h.p. at 3,600 r.p.m., which would have a diameter of 32 in. for 2 per cent. slip.

As has been observed, the astern converter differs from the ahead coupling in the presence of fixed blades; because of these, the blades in the

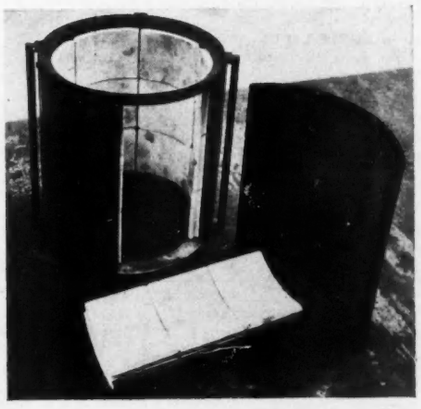

Fig. 5 Refractory flame tube, showing method of securing refractory material to allow expansion.

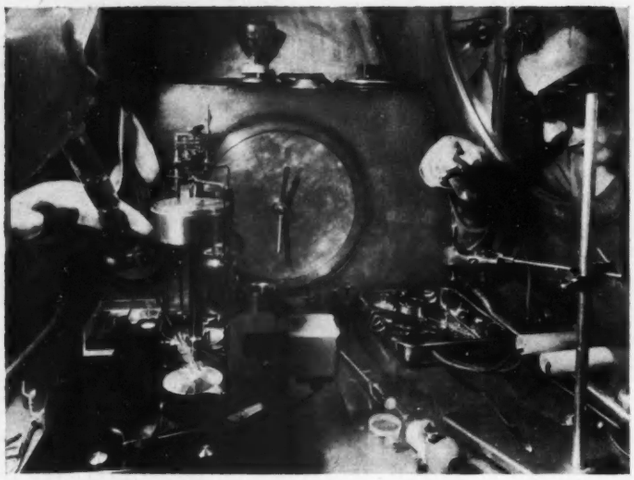

Fig. 6 The sodium-potassium eutectic used as convection heat-transfer medium in hollow gas-turbine blades is handled in an enclosed chamber, or drybox, filled with helium. The end cap is shown being welded on a dummy blade, which has previously been charged with a weighed quantity of liquid metal.

rotating wheels, unlike those in the ahead coupling, are twisted to ensure that the fluid enters the fixed blades and turbine wheel at the correct angle.

The efficiency of the astern converter is lower than the ahead unit due to the losses in the fixed blades; at present the maximum efficiency that has been attained at the design point is 64 per cent. With this efficiency, the astern power available with a hydraulic astern converter is equal to that of an astern turbine in a steam installation. Since the output power is less for the astern converter it has to be designed for a higher slip, since if the coupling efficiency is 65 per cent. the coupling will run at a speed ratio of 0·866 when driving a propeller, and the coupling is designed for this ratio.

An astern converter for the same power as before, that is 7,500 h.p. at 3,600 r.p.m., would have a diameter of 22 in.; the smaller diameter is possible owing to the higher slip.

The friction clutch which is used for prolonged running ahead transmits the whole of the torque, giving 100 per cent. efficiency at this condition. The clutch consists of friction plates hydraulically operated by pressure generated by a forced vortex between the plates. For certain applications a single plate clutch would be suitable.

The clutch friction facings consist of either cast iron against steel, or sintered bronze against steel. When engagement is required, low-pressure oil is supplied to the clutch, which forms a forced vortex generating a high pressure behind the clutch plates, This forces the plates into contact with the corresponding friction surfaces. An orifice is provided at the rim of the plate to obtain a constant flow of oil through the unit so that the clutch can be disengaged by shutting off the oil supply.

The complete transmission is to be installed in the Auris for use in conjunction with the British Thomson-Houston gas turbine previously referred to in ENGINEERING.

A 4,000 h.p. high-pressure steam turbine, eventually to form part of a two-cylinder 7,500 s.h.p., 100 r.p.m. geared set of Pametrada design, which is being built by Hawthorn, R. and W., Leslie and Company, Limited, Newcastle-upon-Tyne, 6, for Overseas Tankship (U.K.) Limited, is at present under test at the Pametrada laboratories. The lower half casing and the rotor of this unit can be seen in Fig. 8.

DOUBLE-CASING HIGH-PRESSURE STEAM TURBINE

The construction of the turbine is the logical development of a large number of successful single-cylinder double-casing turbines and double-casing low-pressure turbines already in service. The design incorporates several novel features which make it suitable for inlet temperatures from 900 deg. F. to 1,200 deg. F.; the limit is set by transfer pressure rather than by inlet temperature. It comprises three main parts, a fabricated outer casing providing the main strength girder for ahead and astern turbines, a cast inner barrel housing the ahead nozzles and blading, and an astern cylinder.

The inner barrel exhausts into the outer casing, which is therefore subject to exhaust steam pressure and temperature, and therefore relatively cool when compared with the inlet temperature (for example, 400 deg. F. compared with 950 deg. F.). The barrel is of very simple design, and is therefore better able to withstand transient temperatures such as occur during manoeuvring. In addition the open exhaust end considerably simplifies the boring of the inner barrel.

The supports for the inner barrel take the form of brackets on the inner surfaces of the side walls. Palm extensions of the horizontal joint flange sit on these brackets, and are located in the axial direction by athwartship keys at the inlet end, directly in line with the steam inlet flange centre line. The inlet-end palms are free to slide outwards, and the exhaust end palms are free to slide outwardly and axially. As hogging depends not only on length between supports but also on temperature difference between top and bottom halves, it will be seen that the short distance between the palms reduces the amount of hogging compared with single-casing construction.

ATHWARTSHIP ALIGNMENT

The athwartship alignment of the inner casing is arranged by keys or chocks on the vertical centre line at each end of the barrel bottom half. The outer casing is extended forward and aft to the turbine feet, and the side and bottom portions of the extensions have triangular openings cut in them, which restrict the area for the flow of heat from the exhaust casing, and also permit differential expansion to take place without destroying the rigidity of the framework.

The bearing pedestals are carried on cross-beams slung on springing plates from a point on the side walls at centre-line level. Since the temperature of the springing plates is not much higher than atmospheric, they provide effective centre-line support for the bearings, and again permit athwartships flexibility. The athwartship position of the beams is again determined by vertical keys on the turbine centre line, locating on the end walls of the exhaust casing.

All steam connections to the inner cylinder are given radial freedom where they pass through the outer casing, either by flexible diaphragms or by piston-ringed sleeves. The astern turbine casing is mounted between the forward extensions of the side walls in such a way as to provide free radial expansion, whilst maintaining true alignment and axial location.

For the full-scale trials, the unit is directly coupled to a Heenan and Froude dynamatic dynamometer capable of absorbing the entire output of the turbine, and will be supplied with steam at 575 lb. per square inch gauge and 940 deg. F. In order to simulate actual running conditions, the required vacuum will be maintained in either the ahead or the astern part of the turbine, whichever is not in use by a plant condenser. Special test instrumentation is fitted for the comprehensive measurement of casing temperatures and of displacements due to pressure and thermal expansion. Steam rate at various powers and speeds is measured by direct weighing of the turbine exhaust after condensation.

ELIMINATING DISTORTION

A series of tests have been carried out on a quarter scale model of the turbine casing to determine the thermal distortions occurring. Steam was supplied to the ahead-turbine outer casing in the same way and in the same condition as the steam exhausts from the full-scale ahead turbine, and the transient distortions determined. Steady steaming tests were also carried out on the ahead and astern casings to determine the distortion expected under steady running conditions. The observations showed that all movements were the result of a general thermal expansion without imposing thermal stresses on any of the components. It was also concluded that no trouble should be expected from gland rubbing.

Fig. 9 shows an instrument which has been developed to enable turbine rotors to be re-balanced in their own bearings on board ship

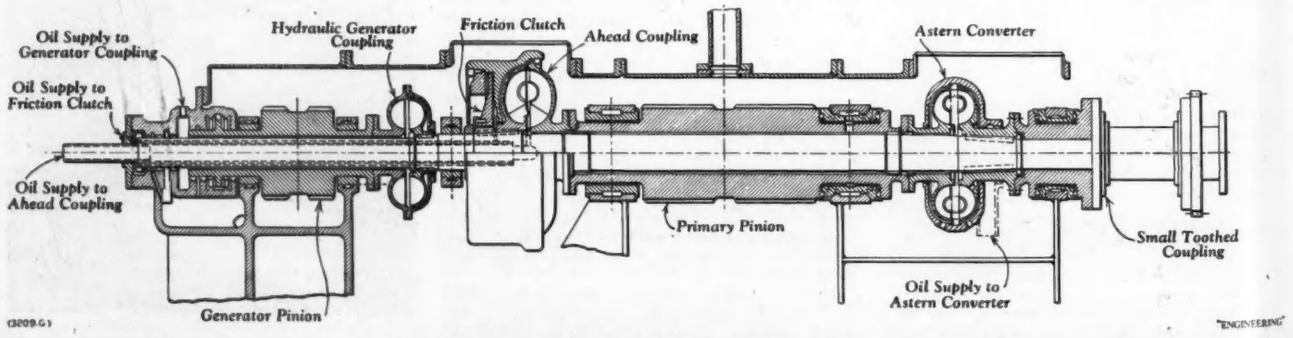

Fig. 7 Hydraulic transmission for a marine gas turbine with auxiliary generator drive. By pumping oil out of the ahead fluid coupling and into the astern converter a vessel can be reversed without recourse to a friction clutch or an astern turbine. The friction clutch is used for steady ahead operation.

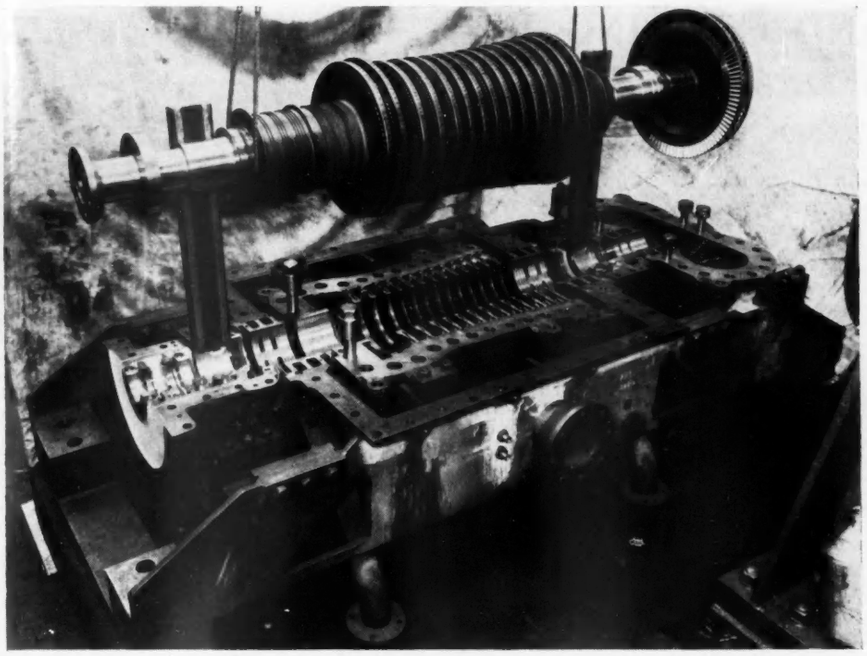

Fig. 8 Double-casing high-pressure steam turbine for two-cylinder 7,500 s.h.p. 100 r.p.m. geared set of Pametrada design. Double-casing construction serves to reduce distortion.

at low speeds. To achieve this, bearing pedestal vibrations caused by the unbalance forces and the phase angle of these forces with respect to a reference on the rotor must be measured.

ROTOR BALANCING IN SITU

The bearing pedestal vibrations are detected by a relative electro-magnetic pick-up, not activated directly by the pedestal, but by a tunable mass-spring system. This mass-spring system can be tuned to resonate at the turbine rotor speed, about 500 r.p.m., so that vibrations at this frequency are magnified up to about 30 times normal. The pick-up generates a voltage output made proportional to the velocity of the vibrations acting on it, so that its output consists almost entirely of the rotor speed frequency, and is in phase with the force causing the vibrations, in this case the out-of-balance force. This voltage is amplified in the instrument and registered on a meter calibrated in thousandths of an inch per second, thus indicating directly the r.m.s. value of the vibration velocity of the bearing pedestal.

The position of the out-of-balance resultant force at a particular bearing is found by measuring the phase angle of the voltage generated by the pick-up mounted on the bearing with respect to a reference voltage pulse, generated once per revolution. This pulse is generated by the passage of an impulse pin, used as a reference marker, on the shaft, past a small electro-magnetic coil attached to the turbine casing. This phase angle is measured by the instrument scaled from 0 to 360 deg.

Thus the vibration velocity, proportional to the out-of-balance resultant force, and the position of this force round the shaft from the reference pin, for a particular bearing pedestal, are indicated by the instrument, and provide the required information for re-balancing to be accomplished. The final degree of balance is claimed to be similar to that obtained by a shop balancing machine.

WATER BEARINGS AND STEAM SAMPLING

The development of water-lubricated bearings is another subject of study at the Pametrada laboratories, and a test machine has been designed for this purpose. It consists of an electric motor and speed-increasing gear driving a journal, against which bearing pads or bearings may be loaded by a " nutcracker " system. Loads up to 500 lb. per square inch can be applied at a speed of 6,000 r.p.m., and long-term tests are carried out to investigate wear.

The function of another apparatus is to collect samples of steam which are subsequently analysed for oxygen, hydrogen, carbon dioxide and other " non-condensable " gases. Steam is collected and condensed over mercury in a glass vessel fitted with a condensing coil. By raising the mercury reservoir the gases above the condensate can be driven into a small detachable capsule which is subsequently connected to an analysis train. Prior to driving the gas sample into the capsule the condensate can be heated by passing steam through the condenser coil, thus ensuring that a minimum of the gas is left dissolved in the condensate. Other fields of research include the examination of fuel ash corrosion and the treatment of fuel oils with additives to reduce corrosive and fouling action.

The work of Pametrada, which is a non-profit making organisation supported both by its member firms and by the Department of Scientific and Industrial Research, is carried on under the direction of Dr. T. W. F. Brown, at Wallsend-on-Tyne, Northumberland.

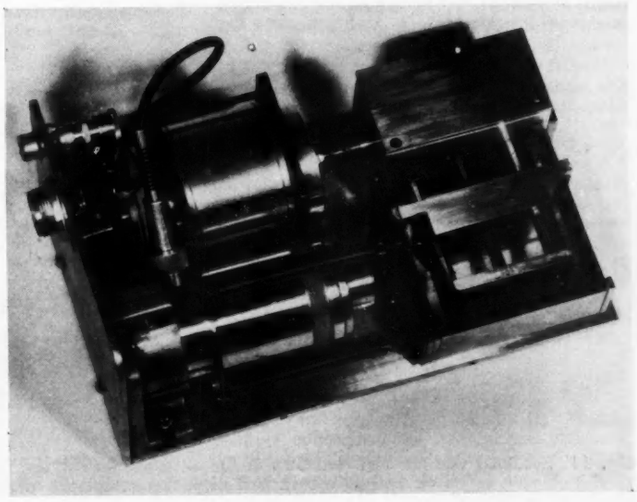

Fig. 9 Instrument developed to enable turbine rotors to be rebalanced in their own bearings on board ship at low speeds.

PREFABRICATED HELIPORTS

Under an arrangement with Standard Heliports Incorporated, Minneapolis, the Dravo Corporation, Fifth and Liberty Avenues, Pittsburgh 22, Pennsylvania, U.S.A., are to manufacture all-steel helicopter landing stations of Standard Heliports' design. It is expected that most of these landing stations will be floating platforms anchored in rivers, lakes, or the sea.

The standard heliport, to be prefabricated at Dravo's Neville Island plant on the Ohio River, consists of structurally-supported sections of open steel grating that serve as landing and take-off pads or cushions for the helicopters.

The open grating and a deflector-pressure surface below it absorb the downwash of the helicopter's horizontal rotor or propeller. Air passages, formed by the foundation pad or the deflector plate below the grating, carry away the excess air churned by the rotor, thus avoiding chops or " bubbles " that could bring a bumpy landing or departure to passengers. Drainage is provided through the grating.

The flight deck is made up of sections, each 10 ft. by 40 ft., with automatic stabilising provided by pivoted floats which cushion the impact of landings and take-offs. Any increase or decrease in weight will automatically change the buoyancy of the heliport and maintain its stability.

The floating platform may be anchored in as little as 2½ ft. of water. One anchorage method is a cable from heliport to shore. Another is a telescoping piling arrangement, whereby during change of tide there is never any projection above the flight deck. The method of anchorage depends upon such factors as shore line, water depth, and tide ranges. A ramp for approach from shore to flight deck, of sufficient strength for ordinary passenger vehicles and mail truck traffic, will be part of the floating equipment.

* * *

PETROL TANKER OF PLASTICS

A petrol tanker using plastics for the tank and parts of the driving cab has been made in Sweden for AB Svenska Shell. On the chassis of a Leyland Comet with 15 ft. 3 in. wheelbase, AB Malmo Flygindustri have built the back, roof and doors of the cab and the 14 ft. long tank. A cold-setting polyester resin was used in combination with glass fibre cloth and glass straw mat. The material has a strength which approaches that of steel, but its specific gravity is 1·7 compared with 7·8 for steel and 2·4 for aluminium. The capacity of the tank is 1,364 gallons and the unladen weight of the tanker is just over 4 tons 16 cwt.

OIL TRANSFER AND COOLING IN RING-OILED BEARINGS

(2) HEAT TRANSFER TESTS

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In the first article by Dr. Özdaş and Professor Ford, published in ENGINEERING *for August* 26, 1955, (*vol.* 180, *page* 268) *they described experiments that had been carried out to test the efficiency of oil transfer in ring-oiled bearings. In the second article, published below, they describe tests carried out on heat transfer in ring-oiled bearings.*

EQUIPMENT FOR HEAT TRANSFER TESTS

The test bearing for the heat-transfer tests was 75 mm. in diameter and 100 mm. long, the general arrangement being shown in Figs. 14, 15 and 16. The journal was of chrome-nickel steel supported in two self-aligning ball bearings and was driven through a flexible coupling from a motor, whose speed could be varied from 50 to 2,000 r.p.m. A reversing switch allowed the motor to be driven in either direction. Fig. 16 shows the lever system for loading the bearing and measuring the friction torque. The system was designed for a maximum bearing load of about 3,000 lb. giving a bearing pressure of 210 lb. per square inch. Two small arms were attached to the bearing housing and carried scale pans for the torque measurements, the free rotation of the housing being limited to a small angle by stops on each side of one of the torque arms. A brass oil ring 120 mm. inside diameter was used and when in operation could be observed through a transparent window fixed into the top of the housing.

The temperature measurements were made with 24 thermocouples of 34 s.w.g. copper-constantan elements of which four were in the housing and 19 in the bearing bush. The bush was of gunmetal 12·5 mm. thick and had an effective bearing length of 100 mm. The design diametral clearance was 0·075 mm. giving a ratio C/D of 1,000. A semi-circular slot 16 mm. wide was provided in the upper half of the bush to locate the ring in the normal manner: the lubricant delivered by the ring was distributed along the bearing by two axial grooves machined in each side of the bush diametrically opposite in a horizontal plane and stopping 12 mm. from each end of the bearing. No grooves were cut in the loaded half of the bush.

MOUNTING THE THERMOCOUPLES

Fig. 17 shows how the large number of thermocouples were arranged in the bush: eight horizontal grooves (A to F) 1·5 mm. wide × 2 mm. deep were cut axially along the bearing and five equally spaced circumferential grooves (sections 1 to 5) were also cut on the outer surface to accommodate rubber bands which held the thermocouples in place. The thermocouple holes, 1·5 mm. diameter, were very carefully drilled at each of the intersections of the circumferential and axial grooves to a depth such that only 0·5 mm. of metal was left beyond the bearing surface. Twin bore vitreosil tubes were threaded over the thermocouple wires to ensure insulation and to transmit the pressure from the rubber bands on to the junctions. Thus a positive contact was ensured between the tip of the junction and the metal immediately below the bearing surface: the junction was very close to the surface and its exact position was known.

The thermocouple wires were taken out through the axial grooves, the whole being further insulated with shellac. Advantage was taken of the axial symmetry and the thermocouples were concentrated in only half of the bearing length (sections 1, 2 and 3) two check thermocouples only being placed in sections 4 and 5. In an attempt to determine the radial temperature gradient—and, by extrapolation, the bearing surface temperature—two couples were located on the outer surface at stations A1 and A2, Fig. 17. A further thermocouple was used to measure the temperature of the oil in the bearing housing; it was introduced through the side of the housing near the oil level indicator.

A Tinsley potentiometer and galvanometer were employed for all temperature readings. The thermocouples were calibrated by the standard methods for the range of temperature required in these tests.

The oils used were the same as in the oil transfer tests.

TEST PROCEDURE

Tests were made with various bearing pressures and speeds using both test oils, as detailed in Table III. The effective immersion in all tests was 10 mm., and ring speed tests were made with both oils.

Tests were also carried out to obtain the friction curve of the bearing. The bearing was lightly loaded (3·2 lb. per square inch and 14·2 lb. per square inch) at runs made at low speeds, to ensure a small rate of shear of the lubricant and thus keep the heat generation at a negligible amount. This gave a suitable range of the non-dimensional group $\frac{\mu N}{P}$ for all the tests carried out at high speeds with different loads. In plotting the friction curve, the temperature of the oil film can be taken as the bearing surface temperature at the point A3 because the difference between the average oil film temperature and that of the bearing surface is negligible.

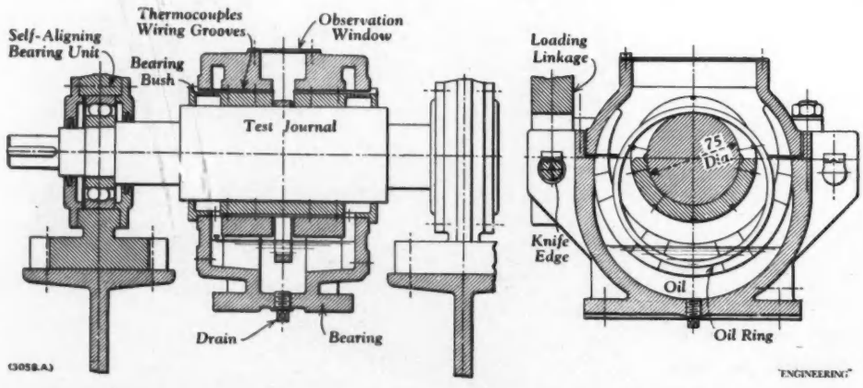

Fig. 14 Sectional side and end elevations of the mounting for the test bearing. The oil ring could be seen in operation through the transparent window.

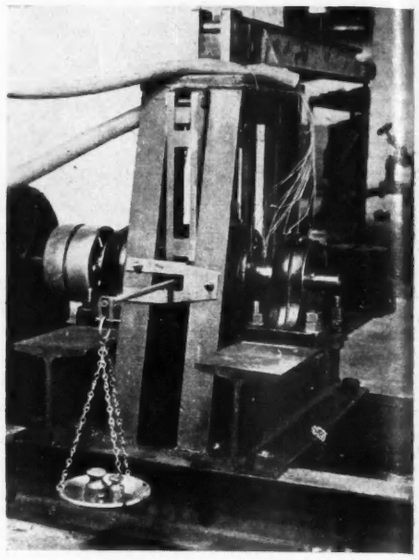

Fig. 15 A general view of the apparatus. The torque measuring scale pan can be seen in the foreground, and the weights loading the bearing on the far side of the apparatus. The heads of the thermocouples can also be seen.

TABLE III.—*Heat Transfer Tests*

1st Series

Pressures $\frac{\text{load}}{\text{projected area}}$	Oil No. 1. Speeds r.p.m.	Oil No. 2. Speeds, r.p.m.
0·6 kg./cm.² (8·5 lb. per sq. in.)	900	
1·0 kg./cm.² (14·2 lb. per sq. in.)	300, 600, 900, 1,200, 1,500	
2·0 kg./cm.² (28·3 lb. per sq. in.)	600, 900, 1,200, 1,500, 1,800	900, 1,200, 1,500
5·0 kg./cm.² (70·8 lb. per sq. in.)	900, 1,200, 1,500	

2nd Series

Pressures	Oil No. 1. Speeds r.p.m.
1·5 kg./cm.² (22·3 lb. per sq. in.)	300, 600, 900, 1,200, 1,500
1·8 kg./cm.² (25·6 lb. per sq. in.)	500
2·2 kg./cm.² (31·2 lb. per sq. in.)	900, 1,500
3·2 kg./cm.² (45·4 lb. per sq. in.)	1,200, 1,500

RESULTS OF THE HEAT TRANSFER TESTS

(a) Friction Curve

The curve of the friction coefficient is plotted against $\frac{\mu N}{P}$ in Fig. 18. The characteristic friction curve is not given in the usual way where $\left(\frac{D}{c}\right)f$ is plotted against the Sommerfeld number $\left(\frac{D}{c}\right)^2\frac{\mu N}{P}$ because accurate measurement of the bearing clearance was difficult. However, the factor $\left(\frac{D}{c}\right)$ was calculated from theoretical considerations and found to be 960—very near to the design value of 1,000 (see Appendix II).

The overall friction force was measured in these tests, but for lightly loaded bearings for which the Sommerfeld number $\left(\frac{D}{c}\right)^2\frac{\mu N}{P}$ is greater than 0·15, it has been shown [1] that the same friction can be taken for journal and bearing surface.

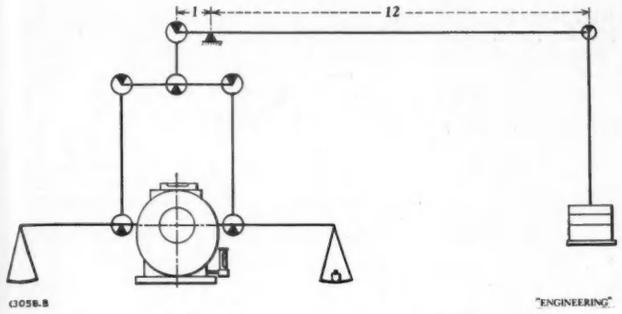

Fig. 16 The lever system for loading the bearing and measuring the friction torque. The two small arms attached to the bearing housing were for the torque measurements.

(b) Ring Speed Tests

In Fig. 19, the ring speed is plotted against journal speed and comparison is made with previous oil transfer test results. The apparent discrepancy arises from the temperature difference between the oil film and the oil bath. The propulsive force on the ring is dependent upon the viscosity of the oil at the journal surface, whereas the drag on the ring is proportional to the oil bath viscosity. Owing to the journal being at a higher temperature than the oil bath, the propulsive force will be about 20 per cent. lower than would correspond to the conditions in the oil transfer tests.

When starting up, the ring operated irregularly owing to the large contact area between the ring side and the bush. It would appear that the width of slot advocated by the German Standard DIN 322, which was used for these tests, is insufficient, and in the rest of the tests a wire bridge was fixed across the slot, so that its legs projected down between the ring and slot. This largely cured the trouble.

The oil supply to the bearing, as shown by the test results, will be discussed in relation to the end leakage (below).

(c) Temperature Measurements

The temperature variation at junction A3 during the warming-up period is shown in Figs. 20 to 22, mainly for a bearing pressure of 28·4 lb. per square inch. In Fig. 22, the oil bath temperature is also shown and the calculated oil film temperature is superimposed. The method of calculation is discussed below.

Figs. 23 to 26 show the temperature distribution obtained in typical tests, while the axial and circumferential distributions are shown in Figs. 27 and 28 respectively.

(d) End Leakage Tests

The oil leaking from the ends of the bearing was collected in later tests.* The ends of the bearing had a circumferential channel cut in the bush with a drain connexion at the lowest point so that the oil reaching the ends of the bearing could be collected and measured. The end loss was compensated by a tap-controlled gravity feed into the sump, to maintain a constant level. A thermocouple recorded the temperature of oil reaching the collecting channel at each end of the bearing. These tests were made on Oil No. 1 only.

The results for the end leakage are shown in Table IV.

TABLE IV.—*Results of the End Leakage Tests*

Speed	Pressure, lb. per sq. in.	Total end leakage, c.c. per sec.	Temperature, deg. C.
300	25·2	0·033	
600	25·2	0·086 0·072	
900	25·2	0·138	47
900	35·5	0·135	
1,200	25·2	0·220 0·221 0·089	
1,200	51·7	0·107	54
1,500	25·2	0·244	59
1,500	35·5	0·156 0·392	63
1,500	51·7	0·191	

Some of the results were erratic, the end leakage being evidently closely dependent upon the degree of " running-in " of the bearing. These fluctuations have been observed both in regard to journal speed and bearing pressure by previous investigators, [2, 3].

OIL FLOW IN THE TEST BEARING

Although the ring speed in these tests was lower than for corresponding conditions in the oil transfer tests, the ring delivered many times the amount of oil needed to make up the end loss. For example, for the conditions of 1,500 r.p.m., bearing pressure (projected area) of 25 lb per square inch, the oil temperature was 59 deg. C., while the bearing surface was about 61 deg. C. Taking 60 deg. C. as the oil film temperature,

$\mu = 6{\cdot}0$ centipoises;
Journal speed = 589 cm. per sec.
Ring speed = 96 cm. per sec.

giving a value $\left(\frac{D}{d}\right)^2 \frac{U\,d}{\gamma} = 145 \times 10^3$, for which $\frac{Q}{nd^3}$ is about 4×10^4 and the oil transfer 4·2 c.c. per second.

Even allowing for the fact that the ring speed in the bearing was about 20 per cent. less than in the test rig, this still represents about ten times the end leakage.

It is clear that the ring provides far more oil than is required to maintain a fluid film and the excess must assist in cooling the bearing to some extent. It does not, of course, pass through the bearing, but the results of Clayton and Wilkie [4] for a force-feed bearing are interesting from this point of view. They found that, although the mean temperature in the bearing varied with change of the oil inlet pressure from 4 lb. per square inch to 160 lb. per square inch, the temperature difference through the bearing did not depend on the supply pressure, that is, on the amount of oil passing through the bearing, and neither did the temperature distribution change essentially. Thus, at 4 lb. per square inch the lowest temperature was about 94 deg. C., as against 84 deg. C. for 80 lb. per square inch supply pressure and 80 deg. C. for 160 lb. per square inch supply pressure; the corresponding maximum (crown) temperatures were 121 deg. C., 111 deg. C. and 108 deg. C., giving a difference of 27 to 28 deg. C. over the whole range. The end leakage varied from 1·6 cc. per sec. to 3·9 cc. per sec. to 5·7 cc. per sec. at the corresponding conditions, but the authors consider that much of the oil passes out through the large clearance diametrically opposite to the crown

* The authors are grateful to Mr. J. C. Hart, B.Sc.(Eng.) and to Mr. J. L. Lee, B.Sc.(Eng.), who carried out these tests.

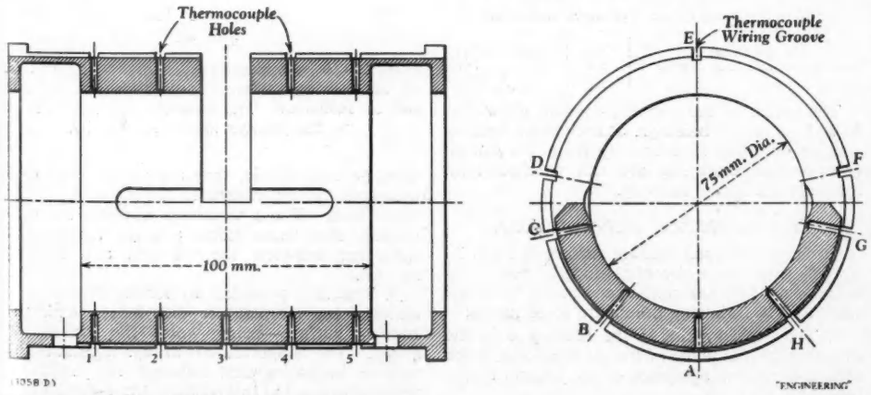

Fig. 17 Mounting for the thermocouples. Grooves A to G are horizontal, 1 to 5 circumferential. Thermocouples were mounted in holes at the junctions of grooves 1 to 5 with grooves A, B, C, G and H.

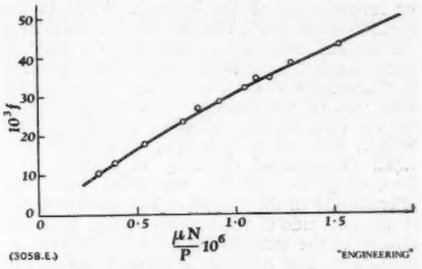

Fig. 18 The coefficient of friction f plotted against $\frac{\mu N}{P}$ where μ is the viscosity, N is the speed and P is the bearing pressure.

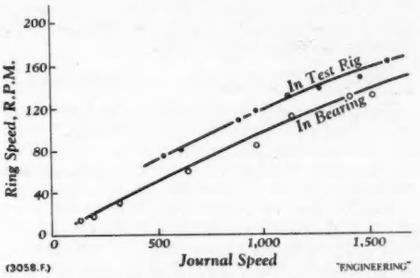

Fig. 19 Ring speed plotted against journal speed for test rig (oil transfer tests) and in bearing (heat transfer tests). The apparent discrepancy arises from the temperature difference between the oil film and the oil bath.

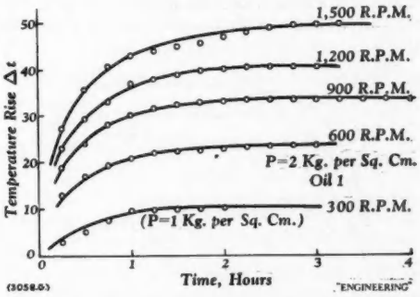

Fig. 20 Temperature rise (deg. C.) plotted against time for varying speeds and with pressure of 1 kg. per square centimetre and 2 kg. per square centimetre, as shown. Oil 1 was used in all cases.

or loaded area of the bearing. Thus in the force-feed lubricated bearing, the heat flow from the critical area of the bearing arc may be likewise through the metal bush, either outwards to the pedestal or directly through the oil on the inlet side of the bearing. This would explain on the one hand the findings of Clayton and Wilkie, that above a certain value there is a rapid decrease of efficiency of cooling with increasing flow and on the other hand, the effectiveness of the oil ring. The oil distributed to the inlet side of the bearing by the oil ring is clearly of the same order as that delivered by force-feed, and on the basis of Clayton and Wilkie's contentions suggests that the surplus oil should be allowed to flood over the unloaded half of the bearing to provide additional cooling. The claims of grooving on the inside of the ring to increase the oil transferred by the ring would appear to be realised only in respect of additional cooling, as the end leakage is easily provided for by a normal ring.

FRICTION IN RING-OIL BEARINGS

Tests were made with light load at low speeds to obtain the friction curve of the bearing. Under these conditions, the temperature of the oil film can be taken equal to that of the bearing surface with negligible error because the heat generation is small. The test results showed a difference of about 4 deg. C. only between the average oil film temperature and the bearing temperature at 600 r.p.m. when equilibrium was reached. The Sommerfeld number $\left(\frac{D}{d}\right)^2 \frac{\mu N}{P}$, or for a given bearing $\frac{\mu N}{P}$, is the hydrodynamic characteristic upon which the coefficient of friction depends and the coefficient can be determined over the operative range by these light-load tests on this

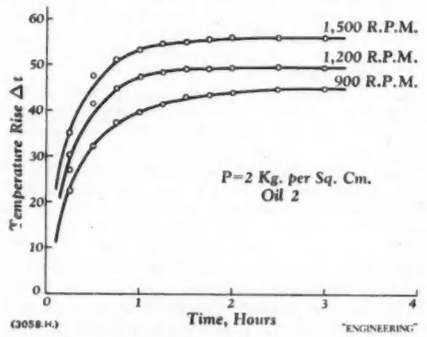

Fig. 21 Temperature rise (deg. C.) plotted against time for varying speeds. Bearing pressure was 2 kg. per square centimetre and oil 2 was used in all cases.

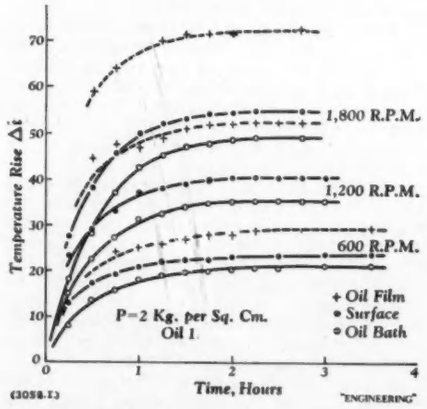

Fig. 22 Temperature rise (deg. C.) plotted against time with a pressure of 2 kg. per square centimetre and using oil 1. Oil-bath temperatures and calculated oil film temperatures are also shown.

account, and can be used as a reference for other tests at high speeds and heavier loads. The coefficient of friction was measured in every test by adjusting the scale weights to balance the bearing: from Fig. 18 the corresponding $\frac{\mu N}{P}$ can be found. Thus, knowing N and P, μ the viscosity can be calculated.

OIL FILM TEMPERATURE

The above measurements allow the oil film temperature to be determined, by the method first proposed by Muskat.[5] It depends upon the validity of hydrodynamic theory, but with this assumption, presents one of the few ways of estimating the film temperature, because from a graph of viscosity against temperature, the temperature can be read off corresponding to calculated viscosity. This method has been used throughout the present work and Fig. 22 shows the oil film, bearing surface and oil bath temperatures in typical tests.

At high speeds the temperature difference between the oil film and the bearing surface is large and by no means negligible. It depends far more on speed than upon bearing load P. These graphs also show how the temperatures change with time during the transitory warming-up period. The bearing surface temperature corresponds to that of the point A3, since an average temperature has no particular meaning.

Averaging the values given by Muskat and Morgan[6] for a force-feed bearing indicates a difference of about 4 deg. C. at 600 r.p.m., while the present results give a difference of 4·2 to 5 deg. C. The observed viscosities of the lubricant were 13 and 12·5 centipoises, respectively in the two cases.

At higher speeds the difference in equilibrium temperatures increased rapidly, becoming about 19 deg. C. at 1,800 r.p.m. It is therefore likely that the friction curves obtained in the usual way, with a few thermocouples embedded in the bearing bush to obtain an approximation to the film temperature, are not very reliable, and consistent results cannot be obtained without reference to the film temperature.

The bearing surface temperature rises very rapidly in the initial stages and 85 to 90 per cent. of the temperature rise has taken place by the end of the first hour. The steady state is generally reached after 3 to 4 hours, depending on the journal speed. Some slight variations were found even after longer periods, but these arose mainly from draughts in the laboratory.

The oil bath and the housing temperatures vary in a similar way to the bearing temperature. The difference in temperature between the oil bath and the bearing surface increased with journal speed, as the following figures will show:

Test Oil No. 1—Bearing Pressure 2 kg. per sq. cm.—steady state

Journal rev. per minute ..	600	900	1,200	1,500	1,800
Temperature difference, bearing surface and oil bath, deg. C.	2·7	3·9	4·9	5·8	6·4

Test Oil No. 2—Bearing Pressure 2 kg. per sq. cm.—steady state

Journal rev. per minute	900	1,200	1,500
Temperature difference, deg. C. ..	5·8	6·3	7·4

The results of the warming-up tests show that in self-contained bearings, although the bearing can be operated satisfactorily from the outset, equilibrium conditions are not reached until after several hours' running.

TEMPERATURE DISTRIBUTION

For the developed bearing surface in Figs. 23 to 26, the circumferential length has been reduced to half the actual compared with the width. The following points are to be noted:

1. The hottest point in the bearing is in the mid-section (the plane of the oil ring) and in the region of nearest approach of the journal to the bearing.

2. While the temperature variation over the bearing surface is not so great as in the tests of

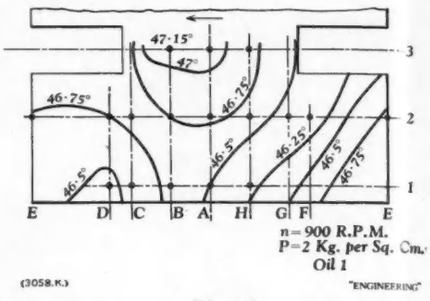

Fig. 23

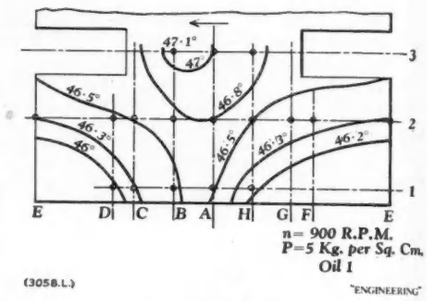

Fig. 24

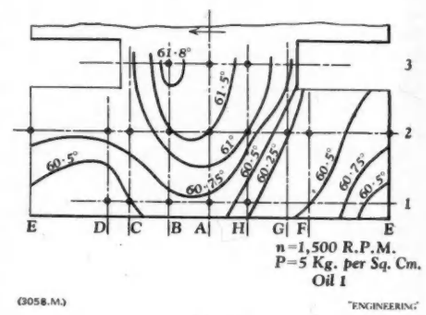

Fig. 25

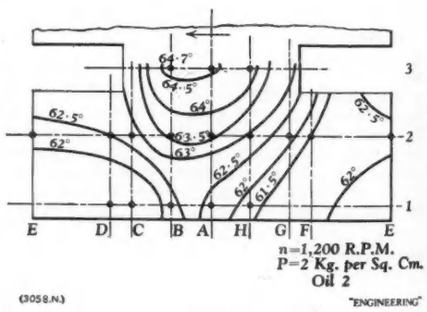

Fig. 26

Figs. 23-26 Temperature distribution in deg. C. of the bearing surface for pressures, speeds and oils as indicated. The numbers and letters refer to the grooves shown in Fig. 17.

Clayton and Wilkie, they are nevertheless considerable, having regard to the lower speeds in these tests. These variations confirm the conclusion that there exists a large temperature difference between the oil film and bearing surface.

3. The slot provided to locate the oil ring disturbs the temperature distribution over the bearing surface—being worse the higher the speed. The temperature is always highest in the middle, indicating that although the journal is flooded with oil at this section, the discontinuity in the bush influences the oil film.

4. As was found by Clayton and Wilkie, the

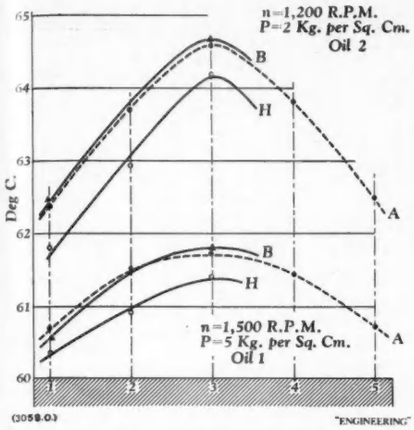

Fig. 27 Axial temperature distribution. A, B and H are the axial grooves in Fig. 17 and positions 1 to 5 are the radial grooves. Temperature increases towards the centre of the bearing.

average temperature is more dependent on speed than on bearing pressure.

The variation of temperature axially is shown in Fig. 27. Curves for axial grooves A, B and H show the same characteristics. However, the temperature at point B3 is higher than at A3 or H3, showing the effect of direction of rotation, the eccentric riding of the journal beyond the load line in the direction of rotation causing the rate of shear to be greater in the region of B3. This is also illustrated by the circumferential temperature distribution Fig. 28.

HEAT DISSIPATION

Thermal equilibrium of a bearing is reached when the heat generated is equal to the heat lost from the outside of the bearing.

The heat generated is given by

$$H_1 = G f W V$$

Where W = the bearing load;
V = journal peripheral speed;
G = a constant, depending on the units of heat and work chosen;
f = coefficient of friction.

Under steady conditions, the temperature of the lubricant reaches an equilibrium value and the heat generated will be equal to the heat dissipated from the bearing, i.e., the steady state is determined by the hydrodynamic characteristics of the bearing and the heat dissipation function. For slow speed bearings, the latter can be represented by Newton's law of cooling, giving the heat loss as proportional to the temperature rise. However, for bearings having higher working temperatures, the heat dissipation function can be more reliably represented by

$$H_2 = K \pi D L (\Delta t)^{\alpha}$$

where H_2 = the heat loss from the bearing;
K and α = constants depending upon the bearing;
Δt = rise in temperature of the bearing above the ambient.
L = bearing length.

The formula gives the constant K in terms of the journal area and at equilibrium

$$H_1 = H_2$$

$$\text{i.e. } \frac{G f W V}{\pi D L} = K (\Delta t)^{\alpha}.$$

The temperature difference Δt can be defined in a number of ways; it can be the temperature rise of the oil film, or of the bearing surface, or of the housing, above the ambient. The first is more common, but demands a knowledge of the oil film temperature—usually not accurately available. Obviously, the housing temperature is a function of the film temperature and the geometry and material of the bearing, but its value can be accurately measured. All three ways were used in the present case, and the values of K and α evaluated for each.

The total heat input can be calculated from the friction curve and the speed, for unit area either of the bearing (actual area = 0·0236 sq. m. or 36·6 sq. in.) or of the housing (actual area = 0·15 sq. m. = 23 sq. in.) i.e. $h = K_3 (\Delta t)^{\alpha}$ k.cals/hr. m² or CHU/hr. in.². In Table V are given the values of K and α for the three ways of evaluating the coefficients, all related to unit journal area.

TABLE V

Temperature differential	Metric units (K. cals./hr. m², deg. C.)		British units CHU/hr. ft.², deg. C.)	
	K	α	K	α
1. Oil film temp. above ambient (Δt_1)	$K_1 = 36{\cdot}5$	$\alpha_1 = 1{\cdot}17$	7·50	$\alpha_1 = 1{\cdot}17$
2. Bearing journal temp. above ambient (Δt_2)	$K_2 = 36{\cdot}5$	$\alpha_2 = 1{\cdot}27$	7·50	$\alpha_2 = 1{\cdot}27$
3. Bearing housing temp. above ambient (Δt_3)	$K_3 = 44{\cdot}5$	$\alpha_3 = 1{\cdot}27$	9·15	$\alpha_3 = 1{\cdot}27$

In case 3, for unit area of the housing, instead of the journal, $K_3 = 7{\cdot}0$.

All these values were averaged from about 16 sets of readings for different speeds, bearing loads and both oils. Based on the journal and housing temperatures the results agree well with the data of Lasche ($\alpha = 1{\cdot}3$) and Muskat and Morgan ($\alpha = 1{\cdot}35$), for the same basis.

APPENDIX I: ASSESSMENT OF THE EXPERIMENTAL ERRORS

Temperature measurements:

A Tinsley potentiometer was used for the temperature measurements, capable of giving one microvolt of potential difference (corresponding to about 0·025 deg. C. for copper-constantan thermocouple in the temperature region employed). The measurements can be taken as accurate to 0·05 deg. C. However, the thermometer used for the room temperature was only accurate to $\pm \frac{1}{2}$ deg. C. and this error may have existed in absolute measurements, although the relative readings (e.g. the distributions) will be accurate to $\pm$ 0·05 deg. C.

Friction torque measurement:

The torque balance was sensible to 1 gram in the pan—i.e., 10 gm. on the journal radius. Compared with the minimum friction force of 2,140 gm. at the bearing surface the error in the resulting torque is less than $\pm$ 0·5 per cent. The average of the torque in both directions was taken to eliminate any uneven loading on the lever arms. To avoid temperature changes as far as possible (there was generally a drop of only 0·1 deg. C. to 0·2 deg. C.), the torque readings were taken 10 minues after reversal.

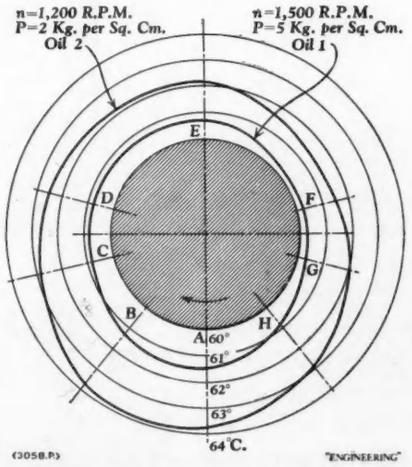

Fig. 28 Radial temperature distribution. The effect of the direction of rotation is very apparent.

Bearing surface temperature:

The tips of the thermocouples being about 0·5 mm. from the surface, the temperatures would be expected to be slightly lower than the bearing surface proper. The two thermocouples at 10 mm. from the bearing surface allow the radial temperature gradient to be estimated by extrapolation from the usual conduction formula

$$\Delta t = \frac{0{\cdot}366\,H}{\lambda L} \log \frac{r_2}{r_1}$$

where H = heat per unit time;
λ = thermal conductivity of bearing shell;
L = bearing length.

The error is negligible.

APPENDIX II: DETERMINATION OF THE DIAMETRAL CLEARANCE

Muskat shows that the coefficient of friction curve for any bearing approaches assymptotically the Petroff line for high values of the Sommerfeld number $S = \left(\frac{D}{C}\right)^2 \frac{\mu N}{P}$.

This gives the Petroff equation as

$$f = \frac{C}{D} \frac{\pi a P D L x S}{W}$$

Where a = the bearing arc;
C the diametral clearance;
P = the bearing pressure.

To determine the bearing arc a, the oil distribution grooves must be allowed for. These are 10 mm. wide on each side of the bush, giving

$$a = 5{\cdot}75$$

and

$$\left(\frac{D}{C}\right) = \frac{f}{18{\cdot}1} \frac{P}{\mu N}.$$

Then $\frac{D}{C}$ can be plotted against $\frac{P}{\mu N}$ and extrapolated to zero to give the clearance for P = 0. The extrapolation gives $\frac{D}{C}$ equal to 960, very near to the design value of 1,000.

REFERENCES

[1] Shaw, C., Macks, F. *Analysis and Lubrication of Bearings*, McGraw-Hill.
[2] Juhlin, A., Pool:, R. *General Discussion on Lubrication*, vol. I, I.Mech.E.
[3] Karelitz, G. B. *Mechanical Engineering*, page 232, vol. 57 (1935).
[4] Vogelpohl, *V.D.I. Forschungsheft*, page 425 (1949).
[5] Muskat, M., Morgan, F. *Trans A.S.M.E.*, page A-131-8, vol. 65 (1943).
[6] Muskat, M., Morgan, F. *Applied Physics*, page 234, vol. 14 (1943).

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WORK BEGUN ON 1,000 MW POWER STATION

The Central Electricity Authority has received the consent of the Ministry of Fuel and Power to proceed with the construction of the 1,000 MW power station on the River Trent at High Marnham in Nottinghamshire.

The consent is for the largest amount of generating plant authorised by the Minister at one time and covers 1,370,000 h.p. of boiler plant and five 200 MW turbo-alternators. Steam will be supplied on the unit system at a pressure of 2,450 lb. per square inch and a temperature of 1,060 deg. F. from each of five boilers which will be of twin furnace design with assisted re-circulation. Re-heating to 1,000 deg. F. is to be employed. The generating sets, which are believed to be the largest in Europe, will be more powerful than most of the Authority's complete power stations. It is expected that an average annual thermal efficiency of 33 per cent. will be obtained, compared with the present figure of 24·08 per cent. for all steam stations.

The High Marnham station will, it is hoped, be ready for operation in 1959.

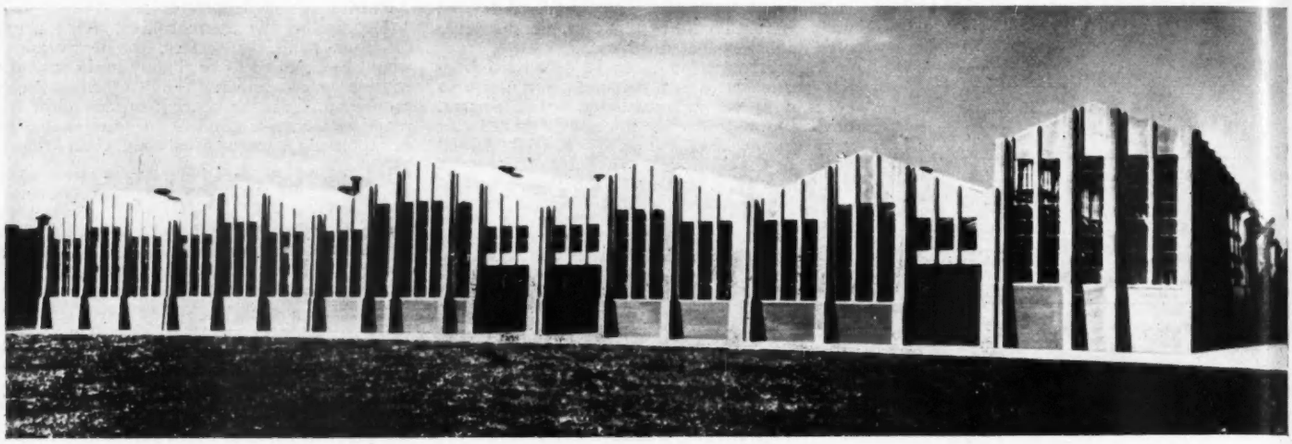

Fig. 1 The extensions to the foundry building of Messrs. Sterling Metals Limited at Nuneaton. Built of pre-cast reinforced-concrete members, concrete was chosen in preference to steel for its resistance to the corrosive atmosphere that is to be expected.

FOUNDRY BUILDING OF PRE-CAST CONCRETE MEMBERS

ROOF SPANS OF 67 FT.

A building, 267 ft. wide by 500 ft. long, of which the frame is built of large pre-cast reinforced-concrete members, is nearing completion at Nuneaton, Warwickshire, as an extension to the iron-foundry premises of Sterling Metals Limited. Designed and constructed by Beecham Buildings, Limited, Shipston-on-Stour, the building comprises six spans as shown in the photograph of the exterior reproduced above, Fig. 1. The eastern span, on the right of the illustration, is 34 ft. and has a height of 40 ft. to the eaves. Of the other five spans, that in the centre is 67 ft. wide and the remaining four are each 50 ft. wide; they are 28 ft. high to the eaves. Outside the main block there are also two additional spans of 34 ft. which run only part of the full length of the building, beginning at the northern end.

Provision has been made over the entire area of the main block for carrying overhead travelling cranes of 5 tons capacity at 18 ft. above floor level. The internal columns, supporting the crane beams and the conventional roof, are spaced at 33 ft. 4 in. centres longitudinally.

The roofs of all spans are pitched at 22½ deg. and the roof cladding consists of "Industrial" aluminium-alloy sheeting, fixed to purlins at approximately 4 ft. 6 in. spacing, these in turn being carried on main roof principals which divide the 500 ft. length of the main block into 30 roof bays each of 16 ft. 8 in. The roof principals of the internal spans are, therefore, carried alternately on the columns and at midspan on the crane beams. The columns in the external walls are spaced at 16 ft. 8 in. centres and directly carry the roof principals. Roof lighting in conventional patent glazing has been incorporated in all spans of the main block, the total roof glass being 30 per cent. of the floor area. The walls are of no-fines concrete, 12 in. thick, to a height of 8 ft. and were cast *in situ* between shuttering clamped to the columns. From a pre-cast cill on the walls rise mullions which divide each bay into three vertical window lights; these fill in the remainder of the wall space up to eaves level. This belt of glazing, about 17 ft. high, runs continuously all round the building, interrupted only by the external columns, mullions, doorways, and two batteries of coke storage bunkers which are incorporated in the structure of the high span. Along the east side of the building there is an open stack yard and loading bay with overhead crane gantry and private railway siding with access to the main London/Manchester line which adjoins the site.

North of the foundry itself, work has begun on a group of ancillary buildings, which will comprise foundry offices and laboratory, electrical sub-station, boiler house, compressor house, and an amenities block with toilet and locker facilities for male and female workers, which will be one of the most up-to-date of its kind in the country. On the north-west side the foundations are under way for a tool shop and pattern shop of 50,000 sq. ft.

PRINCIPLES OF CONSTRUCTION

The structural framing and all the walling elements, with the exception of the no-fines mass walling below the window-cill level, are of pre-cast reinforced concrete manufactured at the builder's works at Shipston-on-Stour, Warwickshire. One of the contributory reasons for selecting concrete members for this work was, apart from the speed of construction possible, the resistance to be obtained to a corrosive atmosphere. It is to be noted that the members are strengthened by plain reinforcement and are not prestressed as no further advantage could have been gained thereby. As for construction employing rolled steel sections, the size of pre-cast concrete members is limited by the difficulties of erection and handling, particularly transporting from the works to the site. In this respect, members cannot generally exceed 40 ft. in length, and the heaviest unit employed at Nuneaton weighed just on six tons.

At Nuneaton, as may be seen from Fig. 2, the roof frames are of three-pinned arch construction, each half being pre-cast as a single L-shaped member, with a leg or vertical section and a rafter arm sloping up at 22½ deg. to the horizontal and abutting the opposing half-arch at the ridge. The ridge block, of a standard concrete mix, is shown in Fig. 3; with only felt pads between the mating faces of the block and rafters the conditions of a pin joint are approximately realised, the bolts being primarily of value for securing the members during erection.

The vertical legs of the arch members are located in channels formed in the upper part of the columns, the hinge being effected by rounding the foot of the leg and seating it in a half-round bearing immediately above the level of the crane beams. The arch thrusts of adjacent spans are balanced against each other except at the outside external columns which act as vertical cantilevers to resist this thrust; in the event of an accident or enemy action leading

Fig. 2 The main roof members are designed as three-pin arch frames with hinged joints at the ridge and at springings in the columns. Heavy pre-cast concrete members are frequently being used, where, a few years ago, rolled steel sections would have been the appropriate method of construction.

Fig. 3 The ridge hinge. It is a pre-cast concrete block and a thin felt pad is used between the mating faces to obtain a nearly uniform pressure. The bolts are primarily for assisting construction.

to a destruction of part of the building, the design is such that complete collapse will not necessarily follow. As the stress in the external columns is primarily due to a bending moment which is greatest at the footings and zero at the springings the columns are battered externally and the reinforcement is concentrated near the internal face. In practice it was found convenient to pre-cast and erect the external columns in two parts, continuity being obtained with starter reinforcement rising from the foundation blocks and running up chases in both parts; after erection the chases were filled.

The outside walls are carried on beam footings between the columns, and the weight of the columns, walls and superstructure together with the thrust from the roof frame together produce a resultant close to the centroid of the arch. This has assisted in keeping the dimensions of the foundations as small as possible.

Most of the concrete floor (and therefore the services below it) had been laid prior to the erection of the superstructure. Erection of the main block commenced in October, 1954, and delivery of components and erection was carried on without a break until the building was completed—in spite of one of the severest winters on record. All the building processes, from weigh batching the aggregates prior to the mixing of the concrete for the roads and floors, to the erection of the pre-cast framework, were highly mechanised. At no time were more than 60 men employed on the site and much of the erection was carried out by one gang of ten men working with two cranes. What is claimed to be the largest permanent prefabricated reinforced-concrete building in the United Kingdom was designed and completed within a year—a marked tribute to the properties of pre-cast concrete members and the design methods adopted at Nuneaton.

WATER RESERVATION SCHEME IN A SUBURBAN AREA

HANDLING WATER FROM CHALK WELLS

Good progress is being made by the Colne Valley Water Company in carrying out their £3 million scheme which, when finished, will ensure an adequate supply of water in the future to the 81 square miles, much of which is densely populated, supplied by the company in Middlesex and Hertfordshire. The scheme includes the building of three pumping stations, the laying of nearly 10 miles of large trunk mains, the construction of the Hilfield Park Reservoir, which will have a capacity of 600 million gallons and of a service reservoir which will have a capacity of 25 million gallons, together with a most up-to-date treatment plant at Clay Lane, Bushey Heath, which will be capable of dealing with 24 million gallons a day.

So far as is known the Hilfield Park Reservoir, which is shown in the accompanying illustration, is probably the first to be built in this country for the storage of raw water pumped from chalk wells. The intention is to fill the reservoir from wells during the winter months—the time of maximum yield of the wells—and to use that water at rates up to 10 million gallons a day during the summer months—the time of maximum demand by the consumers.

EARTH DAM CONSTRUCTION

The reservoir is formed by an earth dam, with clay puddle core, built across a natural valley. The site of the dam is almost at the head of the valley, giving practically no natural catchment area, and therefore normal rainfall will give very little assistance in filling. The rising main from the pumping stations discharges above top water level into open concrete cascades with channels which carry the water into the reservoir. The stored water is drawn off through a valve tower and then passes through micro-strainers before being pumped to the treatment plant.

The whole valley in which the reservoir is built is in the London clay and therefore no special problems arose regarding leakage and cut-off under the dam. The clay was unsuitable as a banking material for forming the dam but it was quite satisfactory for forming the puddle core. Fortunately there were gravel deposits within a few miles of the dam and all the material for the embankment has been imported from these areas.

The dam is approximately half a mile long and at the deepest part of the valley it is 50 ft. high. Owing to the nature of the foundations, which consist of London clay probably 100 ft. or more deep, it was decided that only an embankment dam could be built on the site with safety, since settlement is bound to take place. The upstream face of the dam is at a slope of 1 in 3 and the downstream face, which has a berm 30 ft. below the top of the dam, is at a slope of 1 in 2½.

Many tests were taken to assess the shear strength of the clay foundation and it was found that for depths less than 10 ft. the shear strength was practically constant at about 6 lb. per square inch but that below 10 ft. the shear strength rose suddenly to about 12 lb. per square inch. The low value of the shear strength in the top 10 ft. of clay meant that over the deeper parts of the dam there was insufficient strength in the foundations to resist the tendency of the puddle core to push the two faces of the dam apart. Therefore, where the dam is over 30 ft. high, the top 10 ft. of clay has been excavated over the centre part of the foundations under both the upstream and downstream slopes to form keyways which have been filled with banking material. The clay thus excavated from the keyways was stored, with other excavated clay material, and was used for the puddle core.

The majority of the imported material for forming the banks was dug from some waste land beside the River Colne, about three miles away from the site. This material is a gravel deposit which has quite a high proportion of fine material in it and it is very similar to hoggin. Unfortunately, there was not sufficient material available at this borrow pit to complete the dam and so another pit was worked somewhat nearer the site of the dam, where there is a deposit of sand. This sand, being of poorer quality than the gravel as far as the strength of the embankment is concerned, was only placed close to the puddle core and on either side of it. The sand had a very high clay content and therefore there is little danger of the puddle core drying out through the sand. Still more material was imported from Bushey Heath, where the excavation for the new 25 million gal. service reservoir has been carried out, and this material was very similar to that obtained from the first pit, though having a higher clay content.

The downstream slope of the dam is covered with top soil and sown with grass seed. The whole of the upstream slope is paved with open-jointed concrete blocks laid on a 12 in. gravel filter layer to prevent material from the bank being washed through the joints in the blocks. Below a level of 300 ft. O.D. (see table) the blocks are 5 ft. square and 6 in. thick and were cast *in situ*. Above this level pre-cast concrete blocks 30 in. by 10 in. by 8 in. thick have been used.

Miscellaneous Data:

Volume of excavation	53,000 cub. yd.
Volume of puddle core	26,000 cub. yd.
Volume of imported material for forming banks	330,000 cub. yd.
Capacity of reservoir	600,000,000 gal.
T.W.L.	315 ft. O.D.
Top of bank	320 ft. O.D.
Top water area	105 acres
Bottom of reservoir	270 ft. O.D.

VALVE TOWER AND BRIDGE

A valve tower, housing the draw-off and wash-out pipes, is built at the foot of the upstream slope of the bank near the deepest part of the valley. A channel has been dug to connect the

The Hilfield Park Reservoir, near the Middlesex-Hertfordshire border, will be filled almost entirely by water from wells sunk in chalk beds further north. The earth dam, now nearly completed, with its clay-puddle core, has been constructed across a natural valley sited in the London clay.

washout pipe in the valve tower with the deepest part of the reservoir, thus enabling the reservoir to be drained completely. The three water draw-offs are each 30 in. in diameter and are set at levels of 280, 290 and 300 ft. O.D., respectively. Each draw-off is protected by a basket strainer which can be lifted up to the superstructure for cleaning purposes. The washout pipe is 21 in. in diameter. Because of the negligible catchment area of the reservoir there is no need for a large-scale overflow weir and spillway, and the only provision against overflow is a weir, 12 ft. long, incorporated in the valve tower and discharging into the 21 in. diameter washout pipe.

The superstructure of the valve tower is connected to the top of the embankment by a reinforced-concrete bridge supported on piers which are founded on the natural clay below the bank.

The draw-off and washout pipes are laid in a tunnel which passes right through the dam and connects to the valve tower. This tunnel was originally designed in reinforced concrete, but owing to the national shortage of steel at the beginning of the contract, steel licences were unobtainable and the tunnel was constructed using 12 ft. diameter cast-iron segments. These segments were obtained secondhand from the London Transport Executive and were similar to those used for underground railway tunnels. Where the tunnel passes through the puddle core a concrete "puddle flange" has been built round the cast-iron segments in order to prevent leakage along the line of the tunnel. When the embankment was up to its full height it was found that the cast-iron tunnel segments had distorted under the load of the bank and it was necessary to strengthen the tunnel by constructing a reinforced-concrete lining inside the segments.

The Hilfield Park Reservoir was designed by Mr. Godfrey M. C. Taylor, O.B.E., M.A., M.I.C.E., of John Taylor and Sons, Consulting Engineers, Westminster, London, S.W.1, and constructed by W. and C. French, Limited (Contractors), Buckhurst Hill, Essex.

PUMPING STATION AND TREATMENT PLANT

The water to be treated at Clay Lane is obtained from three pumping stations several miles distant, where there are wells in the chalk. Water can be delivered either directly to the treatment works or to Hilfield Park Reservoir or to both simultaneously.

The capacity of the treatment and filtration works is 24 million gal. a day. When water is pumped directly from the wells, it will receive no treatment until it arrives at the works, but water pumped from Hilfield Park Reservoir will first pass through micro-mesh screens which will arrest algae as well as other floating and suspended impurities. After purification, all the water from whatever source will be pumped to Bushey Heath Service Reservoirs which are on higher ground a short distance south-west of the treatment works.

The treatment works comprise:—

A tank of approximately 170,000 gal. capacity, called the detention tank.

Means for chlorinating the water before other treatment.

Three sludge-blanket precipitators, "Accelators," each 75 ft. in diameter and approximately 20 ft. deep, which can be used for clarifying and softening the water.

Twelve rapid gravity filters each having a filtration area of 1,080 sq. ft. The total filtration area is 12,960 sq. ft. and the speed of filtration at maximum output 78 gal. per sq. ft. per hour.

Waste-water recovery tanks.

Chemical receiving, handling, preparing and measuring equipment for: lime, sulphate of alumina, sodium hexametaphosphate ("Calgon"), activated carbon, chlorine, and sulphur dioxide.

Pure water tanks or filtrate basins, one beneath each row of six filters.

Pumping station in which will be placed two electrically-driven pumps each of 8 million gal. a day and two each of 4 million gal. a day.

Electrical sub-station and transformers.

On the topmost floor of the pumping station there are a chemical laboratory, bacteriological laboratory, offices and the control room.

CONTROL AND OPERATION

There will be a supervisor or operator on continuous duty in the control room who will be able by remote control to stop, start and regulate the pumps in the three distant pumping stations as well as those in Clay Lane pumping station itself.

Waste water from the filters during washing will flow by gravitation to the recovery tanks. After settlement, the supernatant water will be pumped from the recovery tanks back to the Accelators while the concentrated precipitate will flow (possibly with a slight boost) to a lagoon about 4 miles distant at a level 300 ft. lower than the treatment works.

When working at full capacity, the quantity of chemical reagents to be received and stored each day will amount to more than 30 tons. The lime will be delivered by road lorries and will be tipped into a concrete hopper whence it will fall to a rotary crusher. From the crusher it will be elevated and delivered into two silos capable of holding about 14 days' supply.

At the pyramidal bottoms of these silos there will be nibbling wheels which, when required, will draw lime from the silos on to a conveyor, delivering to an elevator which will lift the lime to two small concrete bunkers in the top storey of the chemical house. At the bottoms of the small bunkers there will be electrically controlled revolving feeding mechanisms delivering lime into two continuous slakers which, supplied by water, will deliver lime cream of 15 to 20 per cent. consistency. This will be delivered individually to each of the three Accelators. The stones and other dross from the lime will be separated automatically within the slakers and ejected into trucks standing on the floor below them.

The sulphate of alumina will be dissolved in two tanks at ground level and lifted by pumps to a tank in the topmost storey of the chemical house, whence three pipes will conduct it to the appropriate points in the Accelators. In each pipe there will be a special meter and regulating valve.

Calgon solution will be prepared in tanks at ground level and pumped to a measuring tank from which the appropriate quantities to the three Accelators will be regulated. Carbon will be raised in bags to the topmost floor of the chemical house and emptied into hoppers of dry feed machines; the measured quantities will be conveyed by water to points of treatment. Chlorination can, if desired, be applied to the raw water before it enters the Accelators and will be applied to the filtered water as it enters the filtrate basins. Sulphur dioxide for complete or partial de-chlorination will be applied to the water before it reaches the suction pipes of the Clay Lane pumps.

The detention tank is provided in the scheme, first for the reception and recovery of any water which might accidentally overflow from the filtrate basins and, secondly, to provide a container for use in the event of a failure of electric power affecting the Clay Lane pumps but not the distant well pumps. The use of the tank will afford sufficient time for operators to take whatever steps are necessary to stop the distant well pumps. The tank is also part of the improvisation whereby, having been constructed with baffles for the purpose, it is being used as a chlorine contact tank for a preliminary partial supply from Clay Lane pending completion of the whole works.

It is expected that the use of the waste-water recovery tanks and of the detention tank will limit the loss of water during treatment to that contained in the discarded precipitate, thus maintaining a high efficiency.

When the scheme was designed in 1950, economic conditions in Britain caused severe restrictions on capital investment in waterworks and the Government, in giving permission for the works to be constructed, insisted that they should be capable of construction in sections or phases. This imposed certain limitations and made more difficult the design and the construction of the works than would otherwise have been the case.

The Clay Lane pumping station and treatment plant were designed and are being constructed by the Paterson Engineering Company Limited, Windsor House, Kingsway, London, W.C.2.

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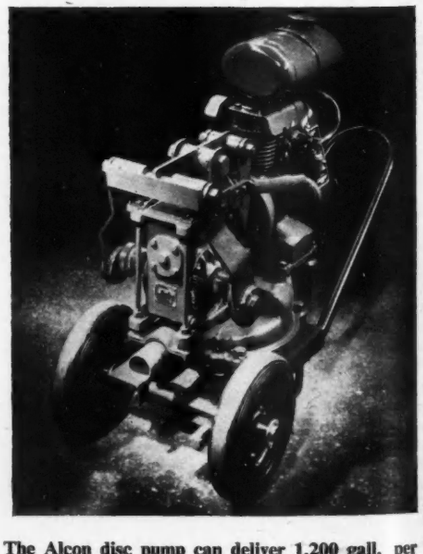
PORTABLE DIAPHRAGM PUMP

For dealing with water containing abrasive material, solids in suspension or sludge in general, Arthur Lyon and Company (Engineers), Limited, 6 Carlos-place, Grosvenor-square, London, W.1, have now produced the Alcon disc pump which is shown in the illustration below. It can also be supplied without the trolley.

The cast-iron pump chamber forms the base of the unit and on it are mounted the engine and the reduction gearbox, making the whole very compact. The pump has been designed for continuous running, and maintenance needs have been kept to a minimum. The only lubrication required is to keep the gearbox and sump topped up with oil; the crank-spindle bearings are grease packed and those of the rocking link and pump do not require lubricating. All other bearings in the connecting linkage are of the rubber bush type. Both diaphragm and non-return valve are made of rubber interleaved with canvas, and the pump spindle and top bearing spindle are of stainless steel. Two lip-type seals are fitted in the pump to prevent leakage from the chamber.

In order to reduce shock and even out the pumping flow, the top casting of the pump is shaped to act as an air bell. Both inlet and outlet pipes terminate in 1½ in. B.S.P. screwed fittings, and they can be in any one of four positions relative to one another. The pump can be fitted with either a J.A.P. or a Villiers four-stroke petrol engine, or a 1-h.p. petrol/paraffin engine. The ratio of the gearbox is 40 to 1. By using a fairly large flywheel, consistent running can be obtained, and as the pump runs at a relatively low speed, it is economical in fuel, being able to run for 12 hours on 1 gallon of petrol. The pump output is 1,200 galls. per hour, and the maximum head and lift are both 20 ft. Without trolley, the unit weighs 180 lb.



The Alcon disc pump can deliver 1,200 gall. per hour of liquid mixed with solid; maximum head and lift are both 20 ft. One gallon of petrol gives 12 hours running.

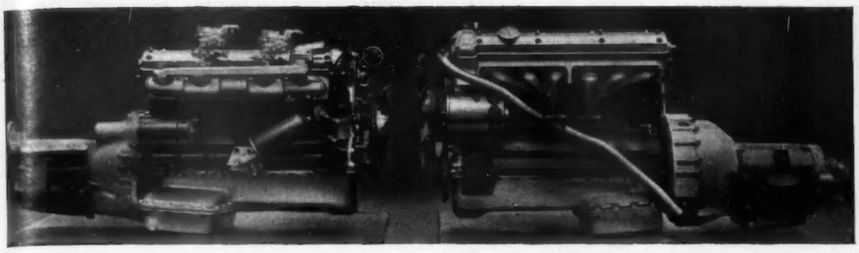


Fig. 1 The 2·4 and 3½ litre Jaguar engines compared. The shallower cylinder block of the new engine is apparent, although for convenience of installation in the saloon car, the height has been increased by down-draught carburetters.

Fig. 2 Piston and connecting rod of the 2·4 Jaguar. The short, stiff rod is internally bored for lubrication of the small-end bush.

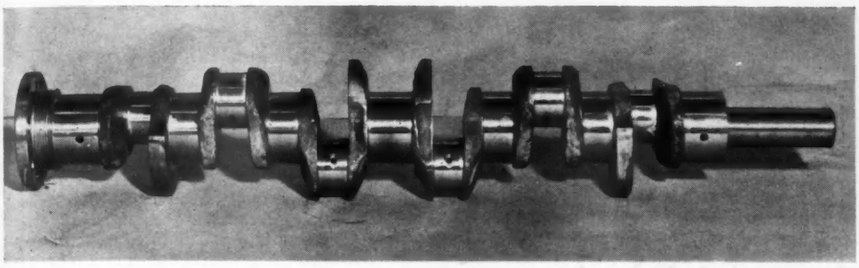


Fig. 3 Crankshaft of the 2·4 Jaguar engine showing large bearing diameters and big overlap between crankpins.

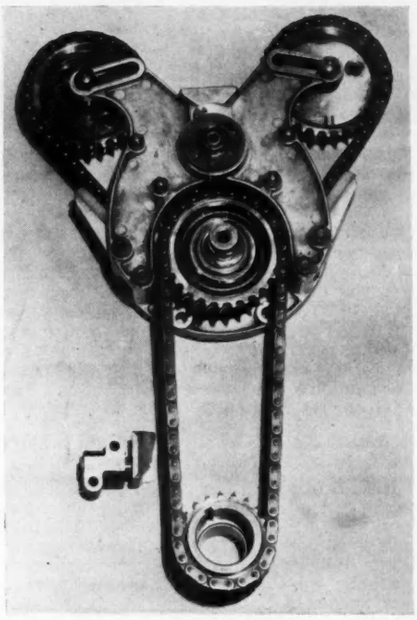


Fig. 4 Jaguar 2·4 camshaft drive train. A Renold tensioner actuated by engine oil pressure bears against the primary chain and two nylon dampers control secondary-chain movement.

The Motor Show at Earl's Court, London (October 19 to 29)

MOTOR CAR DESIGN

CURRENT TRENDS AND PRACTICES: 1—ENGINES

There are signs that the focus of interest in car design is switching from engines to suspensions and structures. The continuous rise in power in America, and the long standing preoccupation of designers in Europe with engine development may soon have to give place to other activities of more real benefit to the user. There is at least one case at the London Motor Show of a new engine being provided for a car where any money available would have been better spent on improvement of the chassis and coachwork. The benefits to be obtained from interconnecting front and rear suspension have now been demonstrated on the 2 CV Citroen and on the latest Packards, and the Citroen DS 19 will do much more to focus attention on improvement of suspension systems. However, there is still much of interest to record in engine development, particularly from the point of view of low-cost production and economical use of materials.

SHORTER STROKES

The new 2·4 litre Jaguar engine shown in Fig. 1 has an interesting background. A four-cylinder unit based on the 3½ litre six has been in existence for some years, and had given good results, but a six was preferred on grounds of smoothness. Mr. W. Heynes, the company's technical director, therefore shortened the stroke of the six-cylinder engine, retaining the same bores. The new cylinder block is extremely squat and stiff, and the crankshaft (Fig. 3), with integral balance weights and large overlaps between main bearing journals and crankpins, is said to be safe up to 7,000 r.p.m. without a damper. The same bearing sizes are retained as for the larger engine, so thin white metals can be used with an entirely adequate safety margin. Important manufacturing economies arise from the fact that cylinder head, camshafts, and other components are interchangeable between the two units, and the same equipment can be used for machining the block. The engine is so low that there is room under the bonnet of the saloon to use downdraught carburetters instead of the usual horizontal type. This is done chiefly to keep the width of the engine down, as it is assembled into the unit body structure from below. The two carburetters are on a light-alloy water-jacketed manifold which is heated by water rising from cylinder head to radiator.

Camshaft drive is by two chains. The primary chain is tensioned by a Renold tensioner, consisting of a synthetic-rubber slipper actuated by engine oil pressure, with a ratchet device to prevent feed back; movement of the secondary chain is damped by two pads of nylon. The pistons have three rings, the top one chromium plated; and the short stiff connecting rods are internally bored to lubricate the little-end bearing bushes. Steel rods are used, as it is considered that the possibilities of fatigue on light-alloy connecting rods argue against their use on engines for general sale. Piston and connecting rod are illustrated in Fig. 2, and the camshaft drive in Fig. 4. A thin steel gasket is used between head and block, crimped locally around cylinder bores and water passages.

The maximum power announced for the engine is 112 b.h.p., without dynamo, fan and other auxiliaries, but there are obvious development possibilities, and it is understood that with three twin-choke carburetters, higher compression, and the other modifications applied to the company's racing engines, an output of 200 b.h.p. has already been achieved on pump fuel.

HILLMAN MINX ENGINE ADAPTED

When the 1,390 c.c. o.h.v. Hillman Minx engine, with equal bore and stroke, was first revealed last year, it was obvious from the two separate starter mountings, that it was destined for other applications. It has now been adapted for the Sunbeam Rapier car, with modifications which put the test-bed output up from 43 b.h.p. at 4,400 r.p.m. to 62 b.h.p. at 5,000 r.p.m. The compression ratio is raised to 8 to 1, a down-draught Stromberg carburetter is used on new manifolds from which the thermostatic flap valve has been omitted to improve gas flow, and the pushrods are now hollow. Mixture from the carburetter impinges on a flat hot plate, and then passes through four passages in the aluminium inlet manifold to four separate inlet ports, which are among the good features of this engine. The designer has also avoided offset connecting rods, an expedient sometimes unavoidable where the bores of an existing engine have to be increased, but now appearing in some new engines straight off the drawing board.

The Standard Vanguard engine has been used almost without alteration for the new model. Long experience has developed this into an economical and durable power unit for many different applications. The inlet-valve diameter has been increased by $\frac{1}{16}$ in., and the ports have been slightly opened out.

Armstrong Siddeley have adopted the opposite course to Jaguar, in using four cylinders from their big engine to form the power unit for the 2·3 litre car, in order to produce a hemispherical-head unit which gives 41 per cent. more power than the in-line valve six from the immediate post-war period, which forms the alternative power unit.

B.M.C. COMPETITION DEPARTMENT

The limited development possibilities available in the design of the current range of B.M.C. engines have already become apparent, necessitating a special cylinder head by Weslake with carburetters on the opposite side, to get adequate port area for the Austin Healey Le Mans engines, and a new cross-flow head for the Le Mans M.G.'s. The newly-created Competition Department, which operates at Abingdon for all

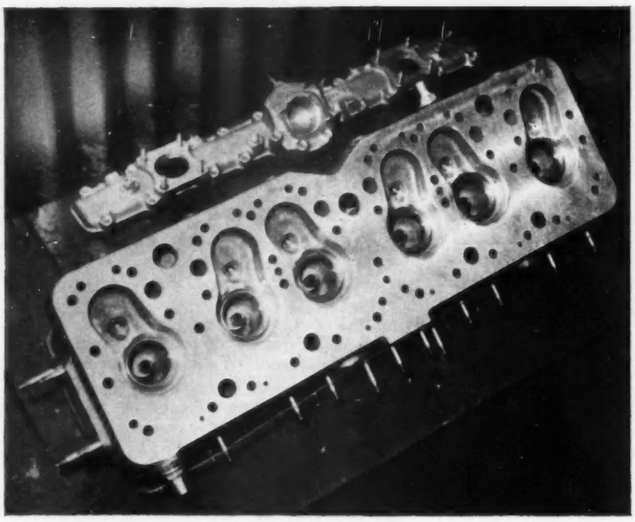


Fig. 5 The cylinder head of the latest Rolls-Royce and Bentley engines has six inlet ports. The inlet gallery is sealed by an external casting which also houses the thermostat controlling the starting mixture.

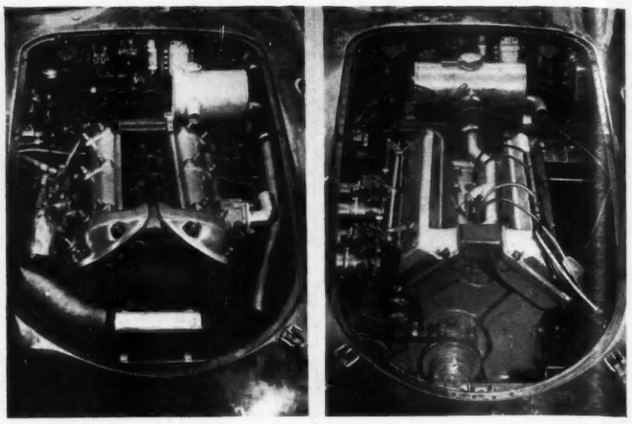


Fig. 6 Two experimental 1½ litre M.G. engines with twin chain-driven overhead camshafts. The cylinder block is adapted from that of the standard pushrod engine.

cars of the Corporation, is now experimenting with twin overhead camshaft heads for the M.G., using the existing block, with a chain case added at the front. Two heads with included angles of 60 deg. and 80 deg. between the valves were tried out in the Tourist Trophy race, and it will be interesting to see what effect, if any, this competition experience has on the design of the Corporation's production power units. Two M.G. engines can be seen in Fig. 6.

BETTER BREATHING AND FUEL INJECTION

Rolls-Royce have also made modifications to secure better breathing by adopting a six-port head (Fig. 5) on the latest series. The inlet gallery is completed by an external casting, which contains the housing for the thermostat operating the choke. These engines have a new type of S.U. carburetter developed after rig tests with transparent plastic models, which led to the adoption of a fuel feed direct to the base of the jet. A synthetic-rubber diaphragm allows the whole jet assembly to be moved vertically for precise setting of the slow-running mixture.

Mercedes Benz are still the only four-stroke engines on public sale with fuel injection, although big investigation and development programmes are in hand in the United States. Injection has now been applied to the vertically mounted engine of the 300S coupé, and as this car is not intended for competition use like the 300SL, a modified valve timing has enabled the full benefits of injection to be obtained in extreme flexibility and in high torque at low speeds. Its power and torque curves are now superior to those of all engines in the range except the 300SL. The 300S engine is shown in Fig. 7.

Daimler Benz have now built up a big business in Diesel cars and have already sold 30,000 of the latest 180D saloon. It now has centrifugal control of injection, giving a later injection at low speeds, and an earlier injection at high speeds, with an overall improvement of power and torque characteristics. The upright engine mounting ensures reasonable accessibility for the injection pump, which appears to be remarkably inaccessible on the 300SL.

The Fiat 600 power unit, Fig. 9, illustrates the special design difficulties which accompany the rear engine position. To save length, the radiator has been placed alongside the engine, but this was apparently not enough, and further space has been saved by omitting waterways between the first and second and third and fourth cylinders. Connecting rods are offset on the crankpins, to leave space for adequate crank webs, and as the engine is designed for continuous operation on full throttle, the bearings are of exceptional size, and are of copper-lead. The engine is unusual in its désaxé layout, with the crankshaft offset 6 mm. in relation to the cylinder bores. This, coupled with a slight offset of the gudgeon pin in the piston, is presumably introduced to reduce side thrust on the piston during the firing stroke. The light-alloy cylinder head makes an interesting casting, with its cast-in inlet manifold, and shrunk-in valve-seat inserts. Weight of the complete power unit, including clutch, gearbox and differential, and all auxiliaries including ducted fan, is less than 240 lb.

In the new Citroen, the engine is its least remarkable feature, but it does employ the same ignition principle as the little 2CV. There is no ignition distributor; a contact breaker works in conjunction with two double coils, producing sparks on both firing and exhaust strokes. This method is also used, with three single coils, on the three-cylinder two-stroke DKW.

GERMAN TWO-STROKE ENGINES

While Britain and Italy still regard four cylinders as the minimum for a small car in large production, the German industry continues to develop a wide range of twin-cylinder power units, mainly two strokes, some air cooled and some water cooled. The small Lloyd, with 400 c.c. two-stroke engine driving the front wheels, is almost unknown in England but is selling at the rate of 5,000 a month in Germany. It has just been joined by a new model, a 600 c.c. air-cooled 4-stroke twin of interesting design, illustrated in Fig. 8. This engine, built in unit with the transmission and final drive, with light alloy for the main castings, has its two parallel cylinders inclined forwards, and a single chain driven overhead camshaft operates inclined valves in a combustion chamber which is between the hemisphere and the penthouse roof in shape. The ignition distributor is driven from the end of the camshaft, and the air from the cooling system can be diverted to provide interior heating. Output is 19 b.h.p. at 4,500 r.p.m.

BUILT-IN OIL-PETROL MIXER

Goliath have introduced a new twin two-stroke of 900 c.c. with water cooling to strengthen their

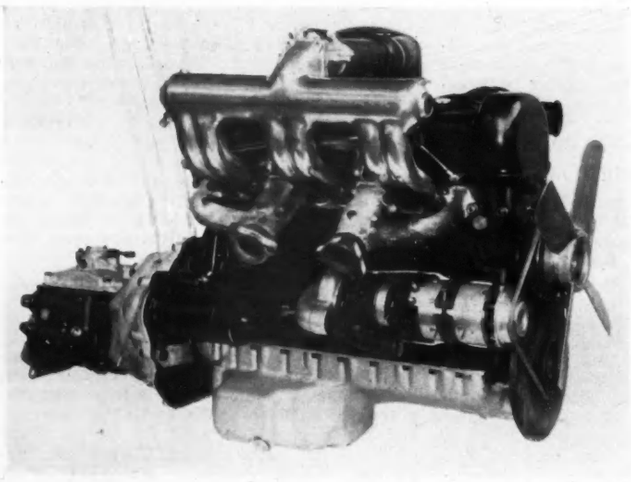


Fig. 7 Fuel injection is now used on the Mercedes 300S sports-touring engine, which is mounted vertically in the chassis, giving easier access to the injection pump than is possible on the 300SL sports car.

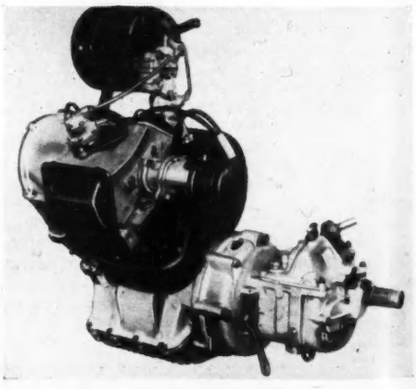


Fig. 8 Typical of unorthodox German light-car units is the Lloyd vertical twin 4-stroke with single overhead camshaft giving 19 b.h.p. from 596 c.c. The engine is a unit with gearbox and front-wheel drive.

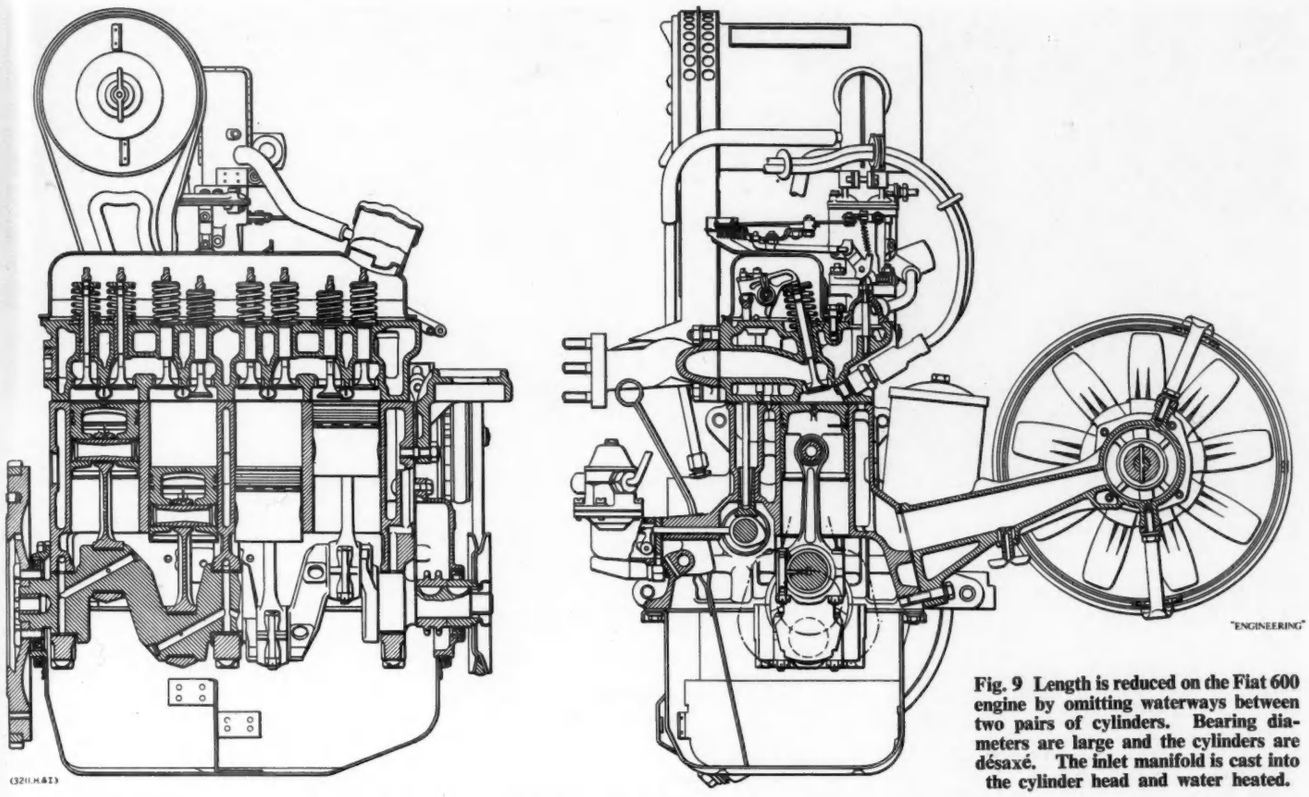


Fig. 9 Length is reduced on the Fiat 600 engine by omitting waterways between two pairs of cylinders. Bearing diameters are large and the cylinders are désaxé. The inlet manifold is cast into the cylinder head and water heated.

competitive position against the three-cylinder DKW. By the use of Bosch direct injection, an output of 40 b.h.p. is obtained at 4,000 r.p.m. from 886 c.c., and specific fuel consumption is much below that of the company's carburetter engines, the saving being about 34 per cent. at low speeds and about 28 per cent. higher up. An incidental advantage of the injection system is that it avoids the need for mixing the lubricating oil with the petrol; German filling stations are equipped to do this, but those overseas are not. The problem has been tackled on the DKW by a special mixer in the fuel filler pipe. The oil is poured in first and the petrol is mixed with it automatically as refuelling takes place.

HIGH COMPRESSION RATIOS IN AMERICA

From the production angle one of the most interesting German engines is the 1½ litre o.h.v. Ford Taunus. Like the American Fords, it uses no valve guides, and the block is strengthened by having no removable cover over the tappet chamber. Its crankshaft (Fig. 10) is a hollow shell casting of large diameter, said to be both lighter and stiffer than a conventional solid shaft. Inserted tubes carry oil to the bearings.

The United States Industry has now completed the switch to the overhead-valve V-eight as the standard power unit. Those who have not been able to design and produce their own buy them out, the American Motor Corporation obtaining their requirements for Nash and Hudson cars from Packard. All are pushrod units, with the two cylinder banks at 90 deg. included angle in a single casting, and all crankshafts run in five main bearings. All have big bores and short strokes, and both dimensions are being increased almost yearly to keep pace with the requirements of the horse-power race for publicity purposes, and to provide the medium speed-torque necessary for acceleration away from the traffic lights with an automatic transmission. They are compact rigid engines, which run smoothly at relatively high r.p.m., but they have more parts than those they replace. Other points against them are sometimes inaccessibility of plugs and ignition distributors, and rapid wear of camshafts, which have 16 cams crowded together.

Compression ratios are as high as 9 to 1, giving specific outputs around 40 b.h.p. per litre, so that American engines are now more highly developed than many European models. Special speed kits are often offered consisting of four-choke instead of twin-choke carburetters, special camshafts and twin-pipe exhaust systems, to please performance enthusiasts without entailing needlessly high production costs on every unit. In such a highly competitive industry, production costs have a strong pervading influence, despite the many apparently extravagant features demanded by the sales departments. At present the Chevrolet engine (Fig. 12) is believed to cost less to make than any of its competitors. The valve gear, the arrangement of which is shown in Fig. 13, is specially interesting. There are no rocker shafts. Each rocker pivots on a pressed-

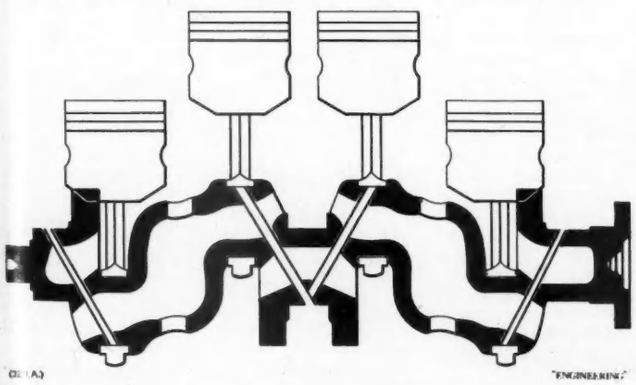


Fig. 10 Hollow cast crankshaft of the 1½litre Ford Taunus engine showing large diameters and inserted tubes for bearing lubrication.

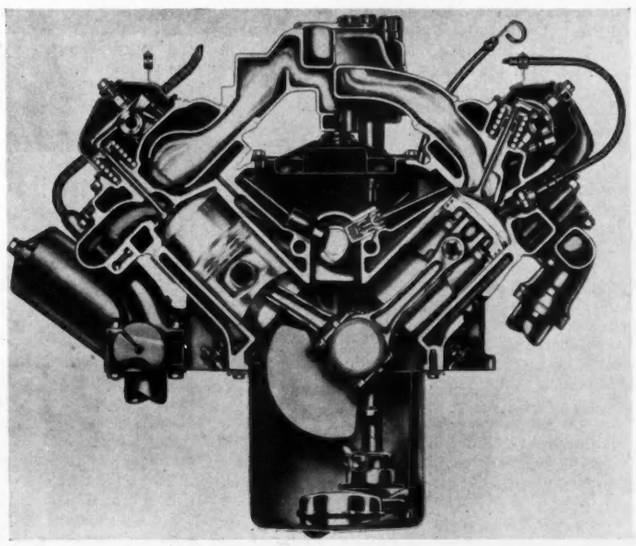


Fig. 11 The V-eight engine for the cheaper Chrysler models departs from the hemispherical combustion chamber to reduce production costs.

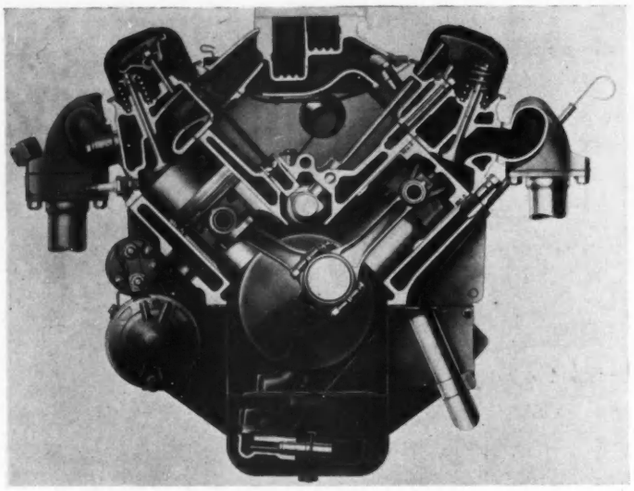


Fig. 12

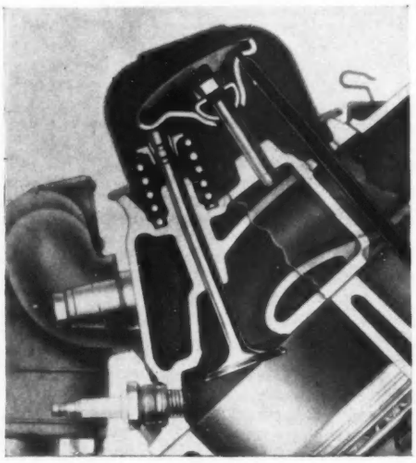


Fig. 13

Figs. 12 and 13 Two views of the Chevrolet V-eight engine show the ball-joint valve gear, hollow pushrods, and single casting comprising tappet chamber cover, inlet manifold and water off-take.

steel ball joint carried on a stud pressed into the head, and the pushrods are made from hollow tubular stock, nipped in at the ends. Valves run directly in the head castings, without guides, as on the Ford engines, and a single casting combines the duties of tappet chamber cover, inlet manifold, and water collection manifold with off-takes to the radiator header tank.

Economic considerations have obliged Chrysler to drop the hemispherical head on the smaller engines for their Plymouth, Dodge and De Soto cars and the cheaper Chryslers, as can be seen in Fig. 11, while retaining the principle for the more expensive models in the Dodge and Chrysler ranges.

The new engines have the valves at a slight angle to each other in a modified combustion chamber called the " Polyspheric," which requires only one rocker shaft per bank instead of two, and simplifies the cylinder-head casting. Chrysler are the latest American recruits to 12-volt electrical systems; improved starting and ignition are among the advantages quoted.

ALUMINIUM COATED VALVES

Aluminium coating is being used as a means of increasing the resistance to high-temperature corrosion and oxidation of cheap valve materials, and General Motors have a method of spraying instead of dipping. The valve is afterwards heated in a flux bath until the sprayed aluminium fuses into a smooth coating. Tests are said to show that treated valves have double the life of uncoated valves.

PHOTO-ELECTRIC CELLS IN COLLIERIES

Some Recent Applications

Mechanisation and fully-automatic supervising and control systems of various types have led to an increasing use of the photocell in industry. In collieries, for instance, this equipment is being largely employed for cage-positioning, checking the closing of skip doors, indicating a slack rope when a cage is resting on keps, automatically controlling artificial lighting and providing a warning system for an aerial ropeway.

The methods employed for these purposes may be illustrated by referring to equipment which has been installed at Thoresby Colliery, Edwinstone, Nottinghamshire, by the General Electric Company, Limited, Kingsway, London, W.C.2. In this colliery, keps are used to locate the cages and photoelectric apparatus is employed to ensure that the winding engine will not start to lower until these have been withdrawn. There is therefore no risk of the engine paying out several feet of slack rope with the keps in position with the result that the cage may drop and the rope snap when they are removed.

CAGE POSITIONING

The photocell and lamp installed for this purpose are aligned so that as the winding drum rotates metal shutters on it interrupt the beam. When the cage reaches a bank level it operates a limit switch at the side of the shaft, thus bringing the photo-electric system into operation. If the winding engine now starts to lower while the cage is resting on the keps the shutters will interrupt the beam and automatically ring an alarm bell.

A photo-electric system has also been installed to prevent skips entering the shaft if the doors are not completely closed. The risk of a door falling open as the skip descends the shaft is thus prevented. To effect this, the door, when shut, is held in position by a catch. When it is opened, however, the catch is lifted and a lamp on the top of the skip is lighted, so that it illuminates photo-electric equipment at the top of the shaft. The signal, which is then transmitted is amplified and gives " skip door open " indications in the banksman's cabin and winding engine house. As soon as the skip door is shut and the catch has dropped home the lamp on the skip is, however, extinquished and the " skip door open " signals are switched off. The beam is produced by two lamps which are supplied from a 24 volt battery so that the warning system is not affected by bulb failure. The photocell units are exposed to a stream of fresh air so that dust will not settle on their surfaces.

A photo-electric system warning people to stand clear has also been installed at Thoresby on the aerial ropeway which carries material to the waste heaps, while the artificial lighting in the engine house, fan house, pit yard, sidings and weighing stage is switched on or off by the same means as daylight fades or is restored.

UNLOADING SPEEDED UP

At Llay Main Colliery, near Wrexham, the two-deck cages, each of which carries two mine cars, are unloaded at one level and the General Electric Company has installed a photo-electric system which has enabled positioning to be accelerated. As the cage rises the light beam is interrupted by a rubber lug when its upper deck becomes flush with the approach rails, thus closing a relay and lighting a lamp, which is a signal to the operator to stop the winder. After the two filled wagons have been removed from this deck the winder is re-started until a second lug intercepts the beam and again energises the lamp, thus signalling to the operator that the lower deck is now flush with the approach rails.

At Barnburgh tipping station in the Manvers coal-preparation plant, the same firm has installed equipment to ensure that the track on either side of the tipper is clear before it can be operated. Blockage, however, causes the interruption of one or other of two beams. A relay which prevents the tippler from operating is thus opened and the green " all clear " light on the control panel is switched off.

★ ★ ★

TRANSPORTABLE ROD CROPPER

A small and easily transportable rod cropper which can crop 2 in. diameter reinforcing rod has been produced by Svenska Motorbon AB, Stockholm, and is marketed in this country by the Kingsland Engineering Company, Limited, 25-37 Hackney-road, London, E.22. Known as the type 52/15, the cropper is driven by a 7 h.p. electric motor which is directly connected to the hydraulic pump. The motor can be 220/350, 400/440, or 550 volts, 50 c/s alternating current.

The machine is operated by the lever, the handle of which can be seen below the main switch in the illustration. Alternatively, the pedal shown just below the foremost spring can be used if foot control is more convenient. The cutting blades are fixed to special seats on the frame and cutter arm, and the blades themselves are cubical in shape so that eight cutting edges can be used in turn. The wheels and drawbar shown in the illustration are optional. Number of cuts per minute is between 15 and 18, the total weight of the machine is 1,060 lb., and the cutter is 12 in. above the ground.

Maximum capacity of this hydraulic rod cropper is 2 in. diameter reinforcing rod. The cutting blades are cubical in shape and the eight edges can be used in turn.

In the assembly rooms of the new factory of Electronic Instruments, Limited, each instrument follows a separate line, moving forward as each stage is completed.

ASSEMBLING ELECTRONIC INSTRUMENTS

New Premises for a Specialist Manufacturer

With the growth of the demand and use of electronics in industry and research laboratories, the Richmond firm of Electronic Instruments, Limited, have built a new factory in Lower Mortlake-road, Richmond, Surrey, which was formally opened on October 4 by the Rt. Hon. the Earl of Halsbury, F.R.I.C., F.Inst.P. The firm particularly wished to remain in their original neighbourhood to retain the skilled labour force that they had built up there since their formation in 1945. Initial training takes about nine months, and it is three years before workers become fully skilled.

The new building is a six-storey block of modern design, with very large window area. Assembly work is carried out on the upper floors, while on the lower ones there are the meter-movement section, the development and chemistry laboratories, machine shop, drawing office and glass-blowing departments, and the clubroom and administration offices. Fire protection is provided by the Minerva nuclear smoke detection system—a product of an associated company. One of the assembly rooms is shown in the illustration, showing how a flow system has been incorporated. Each line of operators deals with a different instrument, and each operator carries out one stage in the assembly, then passes the chassis to the one in front for the addition of the next stage. A considerable amount of sub-assembly work, of such items as resistance boards, is carried out.

One of the original policies of the firm was that only types of instrument not already on the market should be made, and this has been closely followed. It is their claim to have produced the first direct-reading pH meter in Britain, and pH meters of various types still form a large proportion of the output. Over 50 types of electrodes are made. Instruments for insulation testing include a range of meters which will measure up to 20 million megohms, all direct reading, and two laboratory standard instruments are made, and multi-range meter and a valve-voltmeter, for both of which the movements are made at the factory and the scales hand-drawn and calibrated.

For measuring time, the "Chronotron" has been developed, a portable instrument for use in the millisecond and microsecond ranges. The pulse duration is shown by a swinging needle. A portable valve-voltmeter is also made in two versions: the original laboratory instrument, and a more robust model for inter-service use. The latter has been adopted by both the Navy and the Air Force. Another instrument on show was an automatic titrimeter for routine chemical analysis, either in conjunction with standard solutions, or in a coulometric form which dispenses with the need for them.

The most recently developed instrument that is in production is the Vibron electrometer which can be used to measure currents of the order of 10^{-13} amperes and resistances up to 1,000 million megohms. This sensitivity is possible as a vibratory condenser is used in place of thermionic valves in the first stage, converting the signal to an alternating current which can then be amplified and finally re-converted to direct current for measurement. At present, almost all the Vibron units are being used in a nucleonic weight controller which is incorporated in cigarette making machines. With such great sensitivity, only a very weak radio-active source need be used and control of the tobacco flow is almost instantaneous.

* * *

DIESEL-ENGINE DRIVEN SLUSH PUMP

Package Unit of 495 H.P.

The accompanying illustration shows a 495 h.p. medium-speed (800 r.p.m.) package unit consisting of a Diesel engine for driving a slush pump on drilling rigs in the Lobitos oilfields of Peru. The whole unit has been designed to give compactness and accessibility for inspection and maintenance.

The engine, which was manufactured by the English Electric Company, Limited, Queens House, Kingsway, London, W.C.2, has a normal rating of 647 b.h.p. at 850 r.p.m., but has been arranged to give a continuous output of 495 h.p. on the site. It is of the four-stroke cycle single-acting trunk type with wet cylinder liners and individual four-valve cylinder heads. The eight cylinders are in V-formation at an included angle of 45 deg. The bore and stroke are 10 in. and 12 in., respectively.

The cooling water and lubricating oil are cooled by a Serck radiator which, as will be seen from the illustration, is mounted at the free end of the unit. Forced draught is provided by a fan which is driven by a V-belt from an extension to the crankshaft. Rapid warming up of both the water and oil systems when starting from cold can be effected by closing hand-operated louvre shutters. The circulating pumps for both systems are driven through gearing from the free end of the crankshaft.

As a protection against dusty operating conditions, Vokes "Micro-Vee" air filters have been incorporated in the induction system, while magnetic and element-type filters are included in the fuel supply and filters and strainers in the lubricating-oil circuit.

The engine flywheel is coupled through a stub shaft to a Vulcan-Sinclair scoop control fluid coupling, which is fitted with quick-emptying centrifugal valves. This coupling will in turn be connected to the driven machinery through an internal gear-type oil-lubricated flexible coupling made by Crofts Engineers, Limited, Bradford.

The slush pump, which was manufactured by the Oil Well Engineering Company, Limited, Stockport, is operated by a quadruple-drive chain with a pitch of 1½ in. It is of the duplex double-acting type and has a bore of 7¾ in. and a stroke of 18 in. It gives a maximum fluid pressure of 3,000 lb. per square inch.

As it is important that power units of this type should be quickly installed or removed from the pumping unit assembly, the underframe is of the skid type, while the connections for water, air and fuel oil are concentrated on a panel beneath the radiator. As will be seen, the engine unit is covered by a sheet-steel canopy which is attached to girders on the skid frame, while canvas side curtains afford further protection.

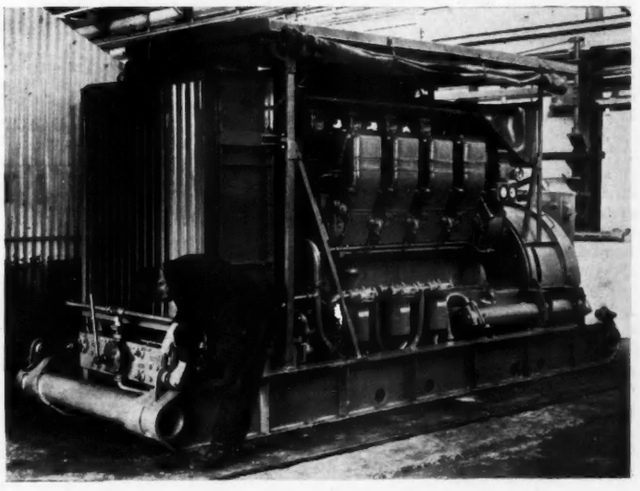
During combined tests at the manufacturers' works, the equipment was run with 6¾ in. diameter liners for nine hours at varying fluid end pressures up to 1,200 lb. per square inch, at which pressure the Diesel engine was fully loaded.

* * *

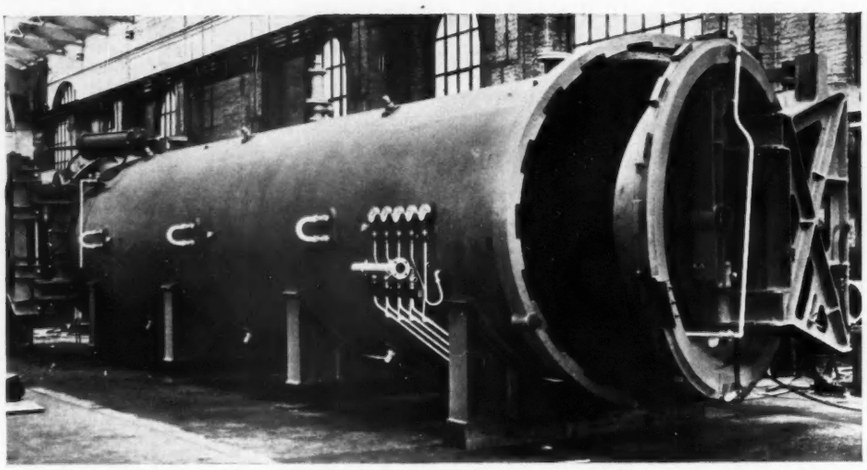
ELECTRICITY SUPPLY IN TURKEY

The Catalagzi power station in the north-western Anatolia district of Turkey, which was opened in 1947 with an initial capacity of 60 MW to supply the local coal mining load and the cities of Ankara and Istanbul, has recently been extended by another 20 MW set and it is expected that it will be completed by two other similar units early next year.

The main contract for the construction of the station was awarded to Metropolitan-Vickers Electrical Export Company, Limited, Trafford Park, Manchester, 17; the principal sub-contractors being Babcock and Wilcox, Limited, Farringdon-street, London, E.C.4, for the coal-fired boilers and auxiliary equipment, and Braithwaite and Company Engineers, Limited, 14 Regent-street, London, W.1, for the civil engineering and building work.



495 h.p. medium-speed packaged Diesel engine and slush-pump unit for the Lobitos oilfields.



The Foster, Yates and Thom autoclave is fitted at each end with quick-acting pneumatically-operated boltless doors. The illustration depicts the autoclave with its inner shell removed to show the steam-heating elements. The working pressure, supplied by compressed air, is 200 lb. per square inch.

AUTOCLAVE FOR METAL-TO-METAL BONDING

Curing Cycle Controlled Automatically

For bonding assemblies of metal aircraft components using Redux or similar metal adhesives, a 1,760 cub. ft. autoclave has been developed by Foster, Yates and Thom, Limited, Blackburn.

In operation, the parts to be bonded are placed in jigs, mounted on bogies, or suspended from a monorail, and a flat rubber diaphragm is clamped over the whole assembly. Air is then exhausted from under the rubber diaphragm, leaving the assembly in vacuum, the covering conforming exactly to the contour of the jigged component.

The vessel is then charged with compressed air to a predetermined pressure, and the temperature raised, the whole being left to remain under heat and pressure for a given cycle, automatically controlled. The heat is circulated within the vessel by means of a fan and internal ducting. On completion of curing, temperature and pressure are reduced, and the assembly removed from the vessel.

The vessel, shown in the accompanying illustration, comprises an outer shell with banks of steam-heated elements mounted round the internal diameter, and an inner shell, or ducting. At each end of the vessel, there is a pneumatically-operated quick-acting boltless door, on one of which is mounted an axial-flow fan for the circulation of the heated compressed air, the motor being mounted externally. The air is drawn from the working space of the vessel through the fan, and forced between the door of the vessel and a shield which is fitted over the fan end door. It is then distributed over the heating elements, and forced along the passage formed by the outer shell of the vessel and the inner shell or ducting, finally impinging upon the dished end of the opposite door, to pass over the work load and recommence circulation. It is intended that the jigged assemblies are fed into one end of the vessel, and withdrawn from the other on completion of bonding.

The autoclave is heated by a positive circulation of steam which enters the heating elements at the points provided along the top of the outer shell and drains to steam traps from an equal number of points situated along the lower part of the shell.

Control of steam, and consequent heating, is achieved by a controlling iron-constantan thermocouple situated in the shell of the autoclave. The iron-constantan thermocouple is one of the resistances of a Wheatstone bridge which controls a diaphragm-operated valve, regulating the steam flow.

The ultimate working pressure is achieved by a combination of heat and a pre-determined pressure, the air being compressed to a required degree, and final pressure being built up by the heating elements. The working pressure is maintained by a diaphragm-operated valve in the air supply line.

At the completion of the curing operation the auto-clave is cooled by the circulation of water, using the heating elements as cooling banks.

The autoclave is provided with four vacuum gauges which connect to points in the shell. Any one of these gauges can be isolated, so that the vacuum can be indicated beneath any particular rubber diaphragm. A pressure gauge is provided for the air pressure within the vessel. An instrument panel carries air and temperature-recording and controlling potentiometers, stop, start, reset buttons, process timer and audible warning alarm, to indicate the stages in the curing cycle. The temperature is recorded at eight points around the shell by means of thermocouples.

General dimensions of the autoclave are as follow: overall length, 45 ft. 9 in.; outside diameter, 9 ft. 2½ in.; maximum width of vessel at doors, 11 ft. 5 in.; diameter inside outer shell, 9 ft.; diameter of working space, 8 ft.; length of working space, 35 ft.; weight of vessel complete, 58 tons; working pressure, 200 lb. per square inch.

* * *

COMBINED SUPPLY CABLE AND LIFTING ROPE

Underwater Television

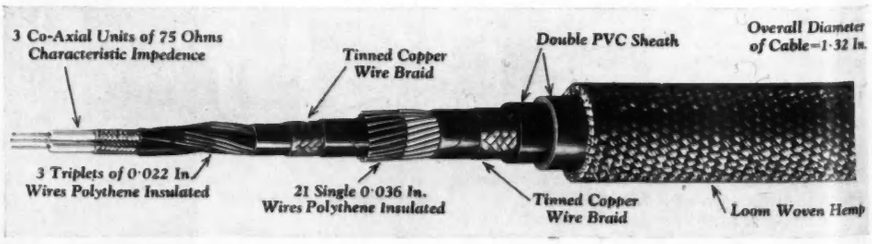
Trials were recently carried out by Pye Limited, Cambridge, on a combined supply cable and lifting rope made by British Insulated Callender's Cables, Limited, 21 Bloomsbury-street, London, W.C.1. The scene of the trials was Zürich in Switzerland, and the television camera used weighed approximately 2½ cwt. A diagram of the cable construction is given below.

The cable, which was made in one length of 1,000 ft., consists basically of a standard polythene insulated multi-unit camera cable, with a double P.V.C. sheath and all enclosed in loom-woven hemp. In detail the cable is made up as follows. At the centre are three co-axial units of 75 ohms characteristic impedance with polythene insulation between the strand and the copper braid and P.V.C. overall. Next are three triplets of 0·002 in. wires, polythene insulated, and then another P.V.C. sheath. This is enclosed in tinned copper braid and another P.V.C. sheath around which lie 21 single 0·036 in. wires polythene insulated. Outside these come a P.V.C. sheath, tinned-copper braid, two separate P.V.C. sheaths and last the sheath of loom-woven hemp, the overall diameter of the composite cable being 1·32 in. An interlocking weave is used for the hemp, which therefore cannot run loose and as the separate threads lie parallel to the axis of the cable, there is no undue strain on the cores. The loom braid is clamped to the camera coupler and so provides the necessary strength to take the load.

For the purposes of the trials the underwater camera was connected to the cable by means of an underwater coupler developed jointly by Pye and B.I.C.C., the cable passing over a pulley of approximately 1 ft. diameter and from there to a capstan of the same diameter. The cable was then flaked on to the deck of the boat in a figure-8 formation to avoid twisting, and connected to the viewing unit and ancillary equipment. The camera was lowered by allowing the cable to slip round the capstan at the rate of approximately 250 ft. per minute for 2 minutes and this was repeated many times. This was a severe test for the cable as the diameters of both capstan and pulleys were smaller than that normally recommended for this size of cable. The rubbing of the hemp finish on the capstan was also a severe test of the durability of the cable. At the same rate of lowering many depths around 150/250 ft. were explored. Previously, it required about 45 minutes to lower the camera to about 500 ft. owing to the danger of the hawser fouling the supply cable.

At all depths the cable resisted any twisting action and allowed the camera to remain in a fixed position indefinitely. Whilst some wear was noticeable after three days of trials, this was not considered unsatisfactory as the woven hemp finish had no protective covering. No electrical failures occurred and even after winding at high speed over small diameter pulleys the circuits were all intact. The cable supported the weight of the camera (approximately 2½ cwt.) for long intervals above the surface of the water without showing signs of stretching and, whilst the woven hemp finish tightened up on the P.V.C. sheath when in the water, no damage to the sheath occurred.

Additional tests included lifting the camera 20 ft. in the air and allowing it to drop to near the surface of the water, the whole strain being taken by the cable. No electrical failures occurred in the cable nor did the textile finish show signs of stretching or fracture. At one time the camera was towed 100 to 200 ft. behind the boat at a speed of approximately 12 knots and the cable stood the test well.


3 Co-Axial Units of 75 Ohms Characteristic Impedence
Tinned Copper Wire Braid
Double PVC Sheath
Overall Diameter of Cable=1·32 In.
3 Triplets of 0·022 In. Wires Polythene Insulated
21 Single 0·036 In. Wires Polythene Insulated
Tinned Copper Wire Braid
Loom Woven Hemp

The weight of the television camera is carried by the outer woven hemp covering which encloses the composite supply cable. There is no tendency for the camera to rotate when it is being lowered.

NOTICES OF MEETINGS

Association of Supervising Electrical Engineers

GLASGOW
Discussion Evening. Glasgow Branch. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. Wed., Oct. 26, 8 p.m.

NOTTINGHAM
"The Advent of the Atomic Age," by Professor L. S. Palmer. Haldane Regional Lecture. Joint Meeting of the Birmingham and Nottingham Branches. Regent Hall, Mansfield-road, Nottingham. Wed., Oct. 26, 7.30 p.m.

Birmingham Exchange and Engineering Centre

BIRMINGHAM
"Industrial Relations To-Day and To-Morrow," by Victor Feather. Fri., Oct. 28, 6.30 p.m. Admission by ticket.

British Institution of Radio Engineers

LONDON
Annual General Meeting, 6 p.m. (Members of the Institution only.) "Recent Advances in Microwave Tubes," by Dr. R. Kompfner, 7 p.m. London Section. London School of Hygiene and Tropical Medicine, Keppel-street, W.C.1. Wed., Oct. 26, 6 p.m.

Building Centre

LONDON
Film on "Prestressed Concrete." Wed., Oct. 26, 12.45 p.m.

Chadwick Trust

LONDON
"Development of the Measurement of Strains in Structures," by R. J. Wilkins. Department of Civil and Municipal Engineering, University College, Gower-street, W.C.1. Tues., Oct. 25, 5.30 p.m. *Note:* The lecture on "The Centenary of London's Main Drainage," due to be held on Nov. 17, has been postponed.

Chemical Society

ABERDEEN
"Electron Transfer Reactions," by Professor C. E. H. Bawn. Aberdeen Branch. Marischal College, Aberdeen. Fri., Oct. 28, 7.30 p.m.

SHEFFIELD
"Chemical Effects of Intra-Molecular Strains," by Dr. G. Baddeley. Sheffield Branch. Department of Chemistry, The University, Sheffield. Thurs., Oct. 27, 7.30 p.m.

Illuminating Engineering Society

LONDON
Report and Discussion on "The 1955 Meeting of the International Commission on Illumination." Lighting Service Bureau, 2 Savoy-hill, W.C.2. Tues., Oct. 25, 6 p.m.

BIRMINGHAM
"Display Lighting," by J. A. Barker. Birmingham Centre. Regent House, St. Phillip's-place, Colmore-row, Birmingham. Fri., Oct. 28, 6 p.m.

BRISTOL
Discussion on "Architectural Problems." Bath and Bristol Centre. Royal Hotel, Bristol. Fri., Oct. 28, 7 p.m.

LEEDS
Chairman's Address on "The Installation, the Engineer and the Local Authority," by R. R. Cooper. Leeds Centre. Lighting Service Bureau, 24 Aire-street, Leeds, 1. Mon., Oct. 24, 6.15 p.m.

Incorporated Plant Engineers

BIRMINGHAM
"Oil Firing," by K. J. Luntley. Birmingham Branch. Imperial Hotel, Birmingham. Fri., Oct. 28, 7.30 p.m.

CARDIFF
"Safety in Industry," by F. W. Thompson. South Wales Branch. South Wales Institute of Engineers, Park-place, Cardiff. Tues., Oct. 25, 7.15 p.m.

LEEDS
"Raising of H.M. Submarine Truculent," with film, by Lieut.-Commander L. Hackman. West and East Yorkshire Branch. The University, Leeds. Mon., Oct. 31, 7.30 p.m.

SHEFFIELD
"Dust Generation and Control in Foundries," by W. H. White. Sheffield Branch. Grand Hotel, Sheffield. Thurs., Oct. 27, 7.30 p.m.

Institute of British Foundrymen

LONDON
"Casting Design," by G. Blanc. London Branch. Waldorf Hotel, Aldwych, W.C.2. Wed., Oct. 26, 7.30 p.m.

BIRMINGHAM
"Fluidity Testing Developments," by Dr. V. Kondic. Birmingham Branch. James Watt Memorial Institute, Great Charles-street, Birmingham. Wed., Oct. 26, 7.15 p.m.

FALKIRK
"Visit to Italian Foundries," by J. Ferguson; and "Visit to German Foundries," by D. McK. Webster. Falkirk Section. Temperance Café, Lint Riggs, Falkirk. Fri., Oct. 28, 7.30 p.m.

SOUTHAMPTON
"Metal-Melting Furnaces and Hot-Blast Cupolas," by F. C. Evans. Southampton Section. Technical College, St. Mary's-street, Southampton. Thurs., Oct. 27, 7.30 p.m.

Institute of Fuel

BIRMINGHAM
"The Impact of Refractory Materials on the Efficient Use of Fuel," by Dr. A. T. Green. Midland Section. James Watt Memorial Institute, Great Charles-street, Birmingham. Thurs., Oct. 27, 6 p.m.

LIVERPOOL
"Some Factors Governing the Welfare of Steam Boilers and Other Pressure Plant," by F. Shapley. Merseyside Sub-Section. Liverpool Engineering Society, 9 The Temple, 24 Dale-street, Liverpool. Wed., Oct. 26, 6 p.m.

NOTTINGHAM
Discussion on "Mineral Matter in Coal: Its Importance and Implication." East Midland Section. Offices of the East Midlands Gas Board, Nottingham. Thurs., Oct. 27, 6.15 p.m.

Institute of Industrial Supervisors

MANCHESTER
"Some Impressions of the Modern American Supervisor," by F. W. Day. North Western Section. Houldsworth Hall, Manchester. Fri., Oct. 28, 7.30 p.m.

Institute of Marine Engineers

GLASGOW
"Watch Keeping and Sea-Going Practice," by H. C. Gibson. Scottish Section. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. Wed., Oct. 26, 7.30 p.m.

KINGSTON-UPON-HULL
"Marine Diesels: Their Production and Applications," by G. K. Baguley. Kingston-upon-Hull and East Midlands Section. Royal Station Hotel, Kingston-upon-Hull. Thurs., Oct. 27, 7.30 p.m.

Institute of Refrigeration

LONDON
Presidential Address by Lord Dudley Gordon. Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, S.W.1. Thurs., Nov. 3, 5.30 p.m.

Institute of Road Transport Engineers

DURHAM
"Aspects of Vehicle Insurance and Accident Assessment," by C. W. Duffie. North Eastern Centre. Three Tuns Hotel, Durham City. Tues., Oct. 25, 7 p.m.

Institute of Welding

LONDON
"The Part of Resistance Welding in Automation," by R. W. Ayres. North London Branch. Manson House, Portland-place, W.1. Wed., Oct. 26, 7.30 p.m.

Institution of Chemical Engineers

MANCHESTER
"A Review of Processes for the Production of Hydrogen," by A. T. Grisenthwaite. North Western Branch. College of Technology, Manchester. Sat., Oct. 29, 3 p.m.

Institution of Civil Engineers

LONDON
"Experiments with Hydraulic Models at Port Lyttelton, New Zealand," by R. C. H. Russell. Tues., Oct. 25, 5.30 p.m.

YORK
"Railway Modernisation and Re-Equipment Plan: Civil-Engineering Works and Problems Involved," by A. Dean. Yorkshire Association. Royal Station Hotel, York. Thurs., Oct. 27, 6.15 p.m.

Institution of Electrical Engineers

LONDON
"An Electro-Static Particle Accelerator," by D. R. Chick and D. P. R. Petrie; "An Electro-Static Analyser for the Absolute Measurement of Proton Energies and the Establishment of Fixed Points on the High-Voltage Scale," by Dr. S. E. Hunt, D. P. R. Petrie, R. Firth and A. J. Trott. Measurement and Control Section. Tues., Oct. 25, 5.30 p.m. Chairman's Address by L. Drucquer. Supply Section. Wed., Oct. 26, 5.30 p.m.

CHELMSFORD
Chairman's Address on "Alternating-Current Switchgear," by M. H. F. Collins. London Graduates' and Students' Section. Public Library, Chelmsford. Tues., Oct. 25, 7 p.m.

CHESTER
"Design, Performance and Application of Miniature Circuit-Breakers, by H. W. Wolff and T. G. F. Atherton. Mersey and North Wales Centre. Town Hall, Chester. Mon., Oct. 24, 6.30 p.m.

NEWCASTLE-UPON-TYNE
"Problems of Hydro-Electric Design in Mixed Thermal-Hydro-Electric Systems," by T. G. N. Haldane and P. L. Blackstone. North Eastern Centre. Neville Hall, Westgate-road, Newcastle-upon-Tyne. Mon., Oct. 24, 6.15 p.m.

NOTTINGHAM
"The Training of the Engineer in the Mining Industry," by J. Jeffrey. East Midland Centre. College of Arts and Crafts, Nottingham. Tues., Oct. 25, 6.30 p.m.

Institution of Engineering Designers

NEWCASTLE-UPON-TYNE
"Design for Welding," by H. Hoscoe. North Esat Branch. Northern Architectural Association, 6 Higham-place, Newcastle-upon-Tyne. Mon., Oct. 31, 7.15 p.m.

Institution of Heating and Ventilating Engineers

LONDON
"The Institution's New Guide: Automatic Controls in Heating and Air Conditioning," by Dr. F. M. H. Taylor. London Associate-Members' and Graduates' Section. Pepys House, 14 Rochester-row, S.W.1. Tues., Oct. 25, 6.30 p.m.

GLASGOW
"Meteorological Data and Design Temperatures," by H. C. Jamieson. Scottish Branch. Scottish Building Centre, 425/427 Sauchiehall-street, Glasgow, C.2. Tues., Oct. 25, 7 p.m.

Institution of Mechanical Engineers

LONDON
"The Value of the Notch Tensile Test," by Professor J. F. Baker and Dr. C. F. Tipper. Applied Mechanics Group. Fri., Oct. 28, 5.30 p.m.

BRIGHTON
"Some Problems in Lubrication and These Substances Called Additives," by A. Towle. Southern Branch. Brighton Technical College, Brighton. Wed., Oct. 26, 7 p.m.

CARDIFF
"The Promotion of Fluid Lubrication in Wire Drawing," by Professor D. G. Christopherson and H. Naylor; and "Experimental Investigation of the Mechanics of Wire Drawing," by J. G. Wistreich. South Wales Branch. South Wales Institute of Engineers, Park-place, Cardiff. Tues., Oct. 25, 6 p.m.

DERBY
Discussion on "Training within Industry." East Midlands Graduates' Section. Works of Rolls-Royce Ltd., Nightingale-road, Derby. Thurs., Oct. 27, 7.15 p.m.

FARNBOROUGH
Discussion on "Gas Turbines," opened by J. A. Barnes. Southern Graduates' Section. Royal Aircraft Establishment Technical College, Farnborough. Wed., Oct. 26, 7.30 p.m.

Institution of Production Engineers

LONDON
Discussion on "The Assessment of Surface Finish." London Graduate Section. Tues., Oct. 25, 7.15 p.m.

BANBURY
"Automation in the Aluminium Industry," by D. A. Ellis. Oxford Section. North Oxfordshire Technical College and School of Art, Bath-road, Banbury, Oxon. Tues., Oct. 25, 7.30 p.m.

LINCOLN
"Design of Transfer Machines under Application to Production," by F. Griffiths and H. W. Holbeche. Lincoln Section. Ruston Club, Unity-square, Lincoln. Wed., Oct. 26, 7.30 p.m.

MANCHESTER
"Cutting Tools: Application and Research," by M. O. Short. Manchester Section. College of Technology, Manchester. Mon., Oct. 24, 7.15 p.m.

OAKENGATES
"Industrial Applications of Electronic Devices," by P. L. B. Buckley. Shrewsbury Section. Walker Technical College, Oakengates, Shropshire. Wed., Oct. 26, 7.30 p.m.

Institution of Structural Engineers

LONDON
Discussion on "The Ultrasonic Testing of Concrete." Thurs., Oct. 27, 6 p.m.

BIRMINGHAM
Chairman's Address by W. D. Christie. Midland Counties Branch. James Watt Memorial Institute, Great Charles-street, Birmingham. Fri., Oct. 28, 6 p.m.

SWANSEA
"Recent Trends in the Design of Industrial Buildings," by A. V. Hooker. Wales and Monmouth Branch. Mackworth Hotel, Swansea. Tues., Oct. 25, 6.30 p.m.

Institution of Works Managers

GLASGOW
"Industrial Engineering: What is it and What is its Function?" by D. J. Lockyer. Glasgow Branch. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. Mon., Oct. 24, 7.30 p.m.

Junior Institution of Engineers

LONDON
"Some Problems from a Structural Consultant's Case Book," by L. Turner. Fri., Oct. 28, 7 p.m.

North East Coast Institution of Engineers and Shipbuilders

NEWCASTLE-UPON-TYNE
Andrew Laing Lecture on "Ferrous Materials in Marine Engineering," by Dr. S. F. Dorey. Literary and Philosophical Society's Hall, Newcastle-upon-Tyne. Fri., Oct. 28, 6.15 p.m.

Royal Meteorological Society

EDINBURGH
"The Scottish Meteorological Society," by Sir Ernest Wedderburn. An address given to mark the centenary of the founding of that Society. Scottish Centre. Department of Natural Philosophy, The University, Edinburgh. Fri., Oct. 28, 5 p.m.

Royal Statistical Society

BIRMINGHAM
"A Method of Labour-Turnover Analysis," by K. F. Lane and Dr. J. E. Andrew. Birmingham Industrial Applications Group. Birmingham Exchange and Engineering Centre, Stephenson-place, Birmingham, 2. Wed., Oct. 26, 6.45 p.m.

SHEFFIELD
"Statistics Without Computers," by H. R. W. Watkins. Sheffield Industrial Applications Group. Grand Hotel, Sheffield. Thurs., Oct. 27, 6.30 p.m.

Sheffield Metallurgical Association

SHEFFIELD
Film Evening. B.I.S.R.A. Laboratories, Hoyle-street, Sheffield, 3. Tues., Oct. 25, 7 p.m.

Sheffield Society of Engineers and Metallurgists

SHEFFIELD
"The Manufacture of Steel Tubes," by E. Lister. Mon., Oct. 24, 7.30 p.m.

Society of Instrument Technology

LONDON
"Some Aspects of the Automatic Control of Distillation Columns," by J. W. Broadhurst. Joint meeting with the Control Section. Manson House, 26 Portland-place, W.1. Tues., Oct. 25, 7 p.m.

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

Association of Supervising Electrical Engineers, 23 Bloomsbury-square, London, W.C.1. (LANgham 5927.)
Birmingham Exchange and Engineering Centre, Stephenson-place, Birmingham 2. (Midland 1914.)
British Institution of Radio Engineers, 9 Bedford-square, London, W.C.1. (MUSeum 1901.)
Building Centre, 26 Store-street, London, W.C.1. (MUSeum 5400.)
Chadwick Trust, 90 Buckingham Palace-road, London, S.W.1. (SLOane 5134.)
Chemical Society, Burlington House, Piccadilly, London, W.1. (REGent 0675.)
Illuminating Engineering Society, 32 Victoria-street, London, S.W.1. (ABBey 5215.)
Incorporated Plant Engineers, 48 Drury-lane, Solihull, Birmingham. (Solihull 3021.)
Institute of British Foundrymen, St. John Street Chambers, Deansgate, Manchester 3. (Blackfriars 6178.)
Institute of Fuel, 18 Devonshire-street, Portland-place, London, W.1. (LANgham 7124.)
Institute of Industrial Supervisors, Bank Chambers, 47 Temple-row, Birmingham 2.
Institute of Marine Engineers, 85 The Minories, London, E.C.3. (ROYal 8493.)
Institute of Refrigeration, Dalmeny House, Monument-street, London, E.C.3. (MINcing Lane 6851.)
Institute of Road Transport Engineers, 69 Victoria-street, London, S.W.1. (ABBey 6248.)
Institute of Welding, 2 Buckingham Palace-gardens, London, S.W.1. (SLOane 9851.)
Institution of Chemical Engineers, 56 Victoria-street, London, S.W.1. (VICtoria 6161.)
Institution of Civil Engineers, Great George-street, London, S.W.1. (WHItehall 4577.)
Institution of Electrical Engineers, Savoy-place, Victoria-embankment, London, W.C.2. (TEMple Bar 7676.)
Institution of Engineering Designers, 38 Portland-place, London, W.1. (LANgham 8847.)
Institution of Heating and Ventilating Enigneers, 49 Cadogan-square, London, S.W.1. (SLOane 3158.)
Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. (WHItehall 7476.)
Institution of Production Engineers, 10 Chesterfield-street, London, W.1. (GROsvenor 5254.)
Institution of Structural Engineers, 11 Upper Belgrave-street, London, S.W.1. (SLOane 7128.)
Institution of Works Managers, 67-68 Chandos-place, London, W.C.2. (TEMple Bar 8324.)
Junior Institution of Engineers, Pepys House, 14 Rochester-row, London, S.W.1. (VICtoria 0786.)
North East Coast Institution of Engineers and Shipbuilders, Bolbec Hall, Newcastle-upon-Tyne 1. (Newcastle 20289.)
Royal Meteorological Society, 49 Cromwell-road, South Kensington, London, S.W.7. (KENsington 0730.)
Royal Statistical Society, 21 Bentinck-street, London, W.1. (WELbeck 7638.)
Sheffield Metallurgical Association, 15 Crescent-road, Sheffield 7. (Sheffield 53674.)
Sheffield Society of Engineers and Metallurgists, University of Sheffield, St. George's-square, Sheffield 1. (Sheffield 24071.)
Society of Instrument Technology, 184 Sherwood Park-road, Mitcham, Surrey. (POLlards 3620.)

THE HUMAN ELEMENT

Working requirements of a heavy capital-investment programme. Young men, national service and the needs of industry. Incentives for wage-earners—higher wages or shares in the profits? Labour's plans for equal pensions. Improving the dock-labour situation. Management courses north of the border.

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Multiple Shifts in Steel

Since the war the steel industry's output has increased by five-eighths but there has been an increase in the number of workers of only one-eighth. This is one of the outstanding features in a recent article in the British Iron and Steel Federation's monthly bulletin which points out that labour productivity, measured as output per man-year, has gone up by about 40 per cent. in the last ten years.

As is well known, this impressive performance has been achieved by a massive programme of modernisation and development involving what must now be well over £400 million. This programme has been accompanied by significant improvements in fuel efficiency and the use of raw materials. The outstanding feature, however, has been the widespread adoption of the continuous working week. By tradition, multiple shifts are worked in the blast furnaces but with the active co-operation of the unions this custom has been extended since the war to the melting shops and, where local arrangements have permitted, to the steel mills as well. The result has been that the steel industry has been able to work its new plant on something between 17 and 21 shifts per week, and it is this fact which has made it possible for the new and expensive plant and machinery to register such impressive increases in output. The steel industry thus provides a unique case of a major industry which has successfully carried through a major capital investment programme and an extension of multiple-shift working without any acute management-labour tension.

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The Call-Up and the Exemptions

The Prime Minister's announcement that the call-up would be modified to yield a reduction of 100,000 in the number of men under arms has failed to excite anyone. At Margate Mr. Attlee charged Sir Anthony with " evading and dodging the issue " and pointed out that to push back the age at which young men are called up by one year without reducing the period of service " is not going to be a great help to industry or education." The conference voted against the abolition of national service, by 4·9 million votes to 1·4 million, but gave enthusiastic support to Mr. Attlee's call for a detailed inquiry into the whole question of national service and the armed forces. Field Marshal Montgomery appeared to agree with them on the need for fresh thinking—indeed he was more scathing than the Labour leaders—but remained adamant on the length of service being kept at two years if anything is to be made out of the men.

The Government may have in mind a policy of deferment of " key men," possibly both on industrial and educational grounds. Already the rules governing the call-up of agricultural workers have been altered to raise the number of deferments to 9,500 out of 15,000 in each age class. If the conditions justifying their deferment exist when their 26th birthday approaches, " they will continue to be deferred and will not be called up on the grounds of age alone."

It is important to know how others will be affected. Will the Government make decisions on receipt of applications by employers, or will they make a detailed statement of policy? The unsettling effects on youths of not knowing how they stand until the last minute are obvious enough. It may, of course, be the Government's wish to use its power to exempt, or defer, in order to assist vital industries in their recruitment and to make more attractive certain occupations where skills are involved and where the intake of apprentices or graduates is inadequate. This may well be in the country's interest, but it may also be thoroughly inequitable.

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Profit-Sharing Under Fire

At the recent Conservative Party conference at Bournemouth both the Prime Minister and the Minister of Labour gave their blessing to the extension of profit-sharing schemes throughout industry. The Minister of Labour, who dealt with it more extensively than the Prime Minister, took care to emphasise the importance of studying the circumstances of each case rather than adopting profit-sharing as a catch phrase.

Last week the Triplex Safety Glass Company, Limited, announced that it was going to abandon its profit-sharing scheme because the unions preferred to negotiate higher basic wages. The company—whose chairman, Sir Graham Cunningham, has done a great deal of public work for industry in general and who would not therefore take an unenlightened view on this subject—has let it be known that the workers cannot have both higher basic wages and a share in the profits. The second development has been an article by Professor Robbins in the Lloyds Bank Review. Professor Robbins is not impressed with the idea of profit-sharing without the workers participating in the ownership of shares as well. To use his own words, " A profit-sharing democracy is not necessarily a property-owning democracy." He much prefers the second of these. If the general trend is to be towards shareholdings by employees, the administrative problem becomes much more complex for the company concerned because questions of trusteeship of funds.

These two views show on the one hand the basic problem of ensuring that a profit-sharing scheme retains the element of incentive for the worker while on the other hand it is important to be quite sure what the basic idea behind profit-sharing is to be. Is it, in fact, to be merely a device for passing on to workers a cut in profits (and so persuading them to accept the idea of fluctuating income which is essential to the idea of equity holdings) or is it to be part of a conscious plan to establish a property-owning democracy?

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" There Ain't No Fund "

Pensions, and the National Insurance Fund, were under discussion at the Labour Party conference at Margate and were the subject of disagreement between the Party executive and the trade union leaders. Some of the main points at issue are the kinds of pensions wanted and how they should be financed. It is believed that the executive favour a flat rate, in keeping with Socialist egalitarian principles, whereas the T.U.C. would rather have pensions proportionate to income as is normal in most company schemes. For three years now arguments have been tossed to and fro without result.

The main concern of the conference was that national insurance should provide adequate retirement pensions and that some means should be found to offset the inroads of rising prices in old people's living standards. Mr. Crossman pointed out that half the men retired from industry at 65 are receiving some kind of superannuation in addition to their old age pensions, and said that the most pressing need was to implement a scheme to cater for the half who did not benefit. On the surface this would appear to invite the firms who at present have a pensions, scheme to transfer their responsibilities to the Exchequer, but a practical way of administering it would be hard to find. The growth of company pensions schemes since the war has been so rapid, however, that unless the Labour movement finds an agreed policy quite soon there may well be few candidates left for their supplementary scheme.

Mr. Bevan, who spoke as the architect of the existing Scheme, called for a complete revision to bring it up to date and was most emphatic on two points: it should be financed by the Exchequer and should incorporate no means test in any shape or form. To those who suggested that some alleviation of cases of hardship could be obtained from the National Insurance Fund he said the Fund did not exist; it was " just an actuarial fiction."

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The Docks Inquiry Opens

The Committee of Inquiry into the working of the Dock Labour Scheme set up by Sir Walter Monckton last August (this page, September 30) began its work last Tuesday under the chairmanship of Mr. Justice Devlin. It will try to uncover the causes, and trace their roots, of the unrest that has plagued the docks since the inception of the Scheme. The employers are confidently expecting a great many changes that will assist productivity, particularly in the conditions of employment and relating to restrictive practices.

While there may be a good many restrictive practices that are a bar to higher productivity, there is also much to be done to win the men's confidence and co-operation, in this case the prerequisite of any progress. Effective leadership and good management could go a great deal farther than any legalistic definitions of rights and wrongs. It is the committee's task to suggest amendments to the Scheme, or completely new working conditions, that may make this possible. To refuse to work the latest types of machines has never in the history of British industry benefited the workers, though the fear of labour-saving devices is strong everywhere, and nowhere stronger than in the docks.

We can only hope that the committee is able from the start to win the respect and confidence of both sides, without which its work would be doomed to failure. In fact there may effectively be three sides: the management, the T. and G.W.U., and the dockers.

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Scotland's Residential Management College

There is quite as much scope in Scotland as elsewhere for the introduction of improved management techniques into industry. The opening last week of a new management study centre by the Royal Technical College in the form of a residential establishment on the edge of Glasgow is therefore to be welcomed. The College has been moving in this direction since as far back as 1928, and in 1947 a Department of Industrial Administration was set up. By this year therefore the West of Scotland was equipped with a series of courses at Glasgow University, at the Scottish College of Commerce and at the Royal Technical College, Glasgow. This new venture by the College now provides a residential course at " Chesters," Bearsden.

" Chesters " will use the cross-fertilisation technique in operation at the Administrative Staff College at Henley, but instead of offering a single course for potential top executives, it will offer several embracing production planning and control, work study, the engineer and cost control, communications, cost reduction, industrial relations, layout and handling in batch production.

Success for this centre necessarily depends on the amount of local support it can muster. This support must be of two kinds. It must be used by local trade and industry to train their promising managers and technicians and it must have local financial support. The management centre could help to bridge that gap which exists to-day in Scotland between theoreticians in management and senior managers in many factories.